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C H E M I S T R Y.

By M. FOURCROY;

DOCTOR OF THE FACULTY OF MEDICINE AT PARIS, OF
THE ROYAL ACADEMY OF SCIENCES, &c.

*Translated from the last Paris Edition, 1789, being the
third, in 5 vols 8vo.*

WITH

An Alphabetical Comparative View of the Ancient and Modern
Names of CHEMICAL SUBSTANCES, with all the TABLES,
and a Complete INDEX.

To which is prefixed by the TRANSLATOR,

A PREFACE, containing Strictures on the History and present
State of CHEMISTRY; with Observations on the Positions,
Facts, and Arguments, urged for and against the ANTIPHLO-
GISTIC THEORY, and the NEW NOMENCLATURE, by
Messrs LAVOISIER, PRIESTLEY, KIRWAN, KEIR, SAGE, &c.

I N T H R E E V O L U M E S.

V O L. I.

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M, DCC, XC.

LEEMING

NATURAL HISTORY

CHEMISTRY

FOR



T O
D R B L A C K.

THIS TRANSLATION
OF THE
LAST EDITION OF A BOOK
WHICH HE HAS RECOMMENDED TO
STUDENTS OF CHEMISTRY,
IS RESPECTFULLY DEDICATED
BY THE
TRANSLATOR.

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WERE the controversy, which was so keenly agitated about the beginning of the present century, concerning the comparative literary merits of the Ancients and the Moderns, to be renewed, the Moderns would now, in all probability, find abler advocates than a Perrault or a Wotton; and even the wit and ingenuity of a Boileau or a Temple would be insufficient to maintain the superiority of the Ancients.

AMONG almost all the nations of Europe, polite literature and philosophy, in all their different branches, have made the most rapid progress since the close of the seventeenth century. Even the science of mathematics, in which perhaps the ancients excelled more than in any other, and which had been successfully cultivated between the æra of the revival of literature and that period, has been since carried to higher perfection, and applied to a greater variety of purposes. How very lately was natural history, in which the order of system has been so happily established, nothing but a confused heap of inaccurate and uncertain facts?

The science of chemistry, till it engaged the attention of Boyle, Boerhaave, and Stahl, appears to have been only in the first stage of a sickly infancy.

THE principles on which men proceeded in the pursuits of science, and the spirit with which they prosecuted them, were long unfavourable to its advancement. Content with the imperfect knowledge of a few general facts, the philosophers of antiquity seldom took pains to establish the certainty or increase the number of those facts; but sought to distinguish themselves as men of genius, and to assert their title to the character of philosophers, by forcing them into unnatural combinations, and distorting them to support fanciful hypotheses. No qualities are more necessary to him who would contribute to the advancement of science than humility and patience: but these qualities scarce appear united in the character of any of the most celebrated ancient philosophers; nay, whether ancient or modern, those whom we honour as men of genius and philosophers, have been too generally distinguished by the opposite qualities of pride and impatience, to deduce general inferences, without entering into a full examination of particulars. Synthesis, which was long the established mode of prosecuting scientific researches, deserves no higher character than that of an ingenious way of imposing on one's self and others by false positions and unfair conclusions. It is indeed nothing but a partial, a false analysis. You have some general inaccurate knowledge of the nature and relations of some being; and you conclude, that you know every thing concerning it; that you are intimately acquainted with its nature; that all its relations must be consistent with your ideas of it; and that it
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can suffer no changes but those to which you perceive it to be liable. Such is synthesis *.

BUT, till of late, scarce any of the other sciences was in so unfavourable circumstances as chemistry. The Egyptians, Greeks, and Romans, *might be* skilful chemists: but we do not know that they *were*. The Arabians involved this science in mystery. Their ignorance of the phenomena of nature, and the absurd notions which they entertained concerning superior beings, and *their* influence on the affairs of this world, naturally led them to involve every thing with which they were acquainted in circumstances of mystery and wonder. The Saracens were the first who practised chemistry in modern Europe. Their neighbours, to whom they communicated their chemical knowledge, were still more ignorant than themselves. They who had received so many religious mysteries with such profound reverence, such fond credulity, were *excellently* prepared for adopting chemical mysteries in all their absurdity. Gold, too, was scarce as it was precious; and longevity, amidst all its miseries, is still eagerly coveted. Hence came the alchemical doctrines of the Arabians to be so eagerly embraced in Europe, and improved into absurdities still wilder by Lully, Paracelsus, and the Rosicrucian brethren. Fancy established her dominion in a place where we should not naturally expect to find *her* either seeking or obtaining admittance. Taking up her abode in the laboratory, amid furnaces, cupels, cucurbites, and aludels, she amused herself in superintending processes of digestion, distillation, rectification, and such others. Useful discoveries, when made, were owing

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* Chemical synthesis is not here meant.

solely to accident; absurd hypotheses and ridiculous theory were the only things here produced by the exertions of human ingenuity. By degrees, however, alchemy fell into discredit, and mystery was almost entirely rejected as inconsistent with science. The facts have been by degrees connected into a system. Capricious and unmeaning processes have gone into disuse. Chemists have learned, that some degree at least of plausibility is no less necessary to their theories, in order to prevent them from being absolutely ridiculous, than to those of the natural or the moral philosopher. Their operations are now conducted upon scientific principles; they no longer proceed blindly like the mechanic, or a pupil in arithmetic, who follows his rules without inquiring how it comes that the operations which they direct bring out the answer required.

WE are all sensible what an important rank heat and light hold among the phænomena of nature. We have constant occasion to take notice of them: And in some of those sciences which depend on the observation of the appearances displayed in the material world, to mark their modes of existence and their influence, must surely be a capital part. Heat, not the sensation to which we give this name, but the cause of the sensation, naturally engages the attention of the chemist in a very high degree. Accordingly, as soon as chemistry began to assume the character of a science, chemists set themselves eagerly to ascertain the various phænomena of heat; to trace it as it arises and again disappears.

THE theory of *phlogiston*, which has so long made
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an eminent figure in all chemical reasonings, and has been so intimately incorporated with the whole body of facts on which the science is established, originated from some of the earliest attempts of philosophical chemists to establish general principles with respect to the phænomena of heat. We behold flame, we see bodies consumed, we feel a pleasing, and at length a painful sensation, when we approach within the sphere of these phænomena. We call, in popular language, the cause of these phænomena *fire*; that which acts immediately on our organs, and on the bodies consumed, we call *heat*; and to the sensation thus communicated to us we give likewise the name of *heat*. Now, is this fire, or flame, or heat, as much a material body as a piece of wood, or glass, or stone, or any other grosser substance? If it be, whence does it arise? and what becomes of it? We neither saw nor felt it before the fire was kindled; and when the fuel is consumed, it no longer appears.

In answer to these inquiries, the ingenious Stahl and his followers tell us, that fire or heat is actually a material body; and, like other material bodies, liable to be modified by the influence of circumstances. In bodies liable to be burnt, it exists in a latent state: place them in the circumstances in which combustion is produced,—you then behold it appear, perceive it operate, and feel its influence. In those bodies, though it exhibit no flame, nor produce the other effects which it accomplishes on surrounding bodies when developed by combustion, yet it is far from being absolutely dormant. Whatever qualities combustible bodies lose by combustion, those they owe to phlogiston or the latent principle of fire. Bodies which lose none of their principles by combustion must be incombustible, and
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can contain no phlogiston. An incombustible body may be volatile, and therefore reducible to vapour by the action of fire; but its principles cannot be divided; it cannot be decomposed by burning. The latent principle of fire does indeed elude our investigation; we cannot obtain it, like the other principles of bodies, in a separate state; whenever it escapes or is expelled out of one combination, it enters into another; it operates unseen; but still it operates. When it makes its way out of a burning body, it mingles in the surrounding atmosphere; and no fact is better known, than that air is altered in its nature, and acquires new qualities, in consequence of being exposed to the contact of a burning body.

SUCH are the general ideas on which the theory of phlogiston is founded. It is natural and plausible, and justified by many facts. That this substance has never appeared in a separate state, cannot well be considered as a proof of its nonexistence: It is not the only material substance of which the essence is too subtle for our observation. When a number of facts, all referable to this general principle, were discovered, it was very natural for those who observed the analogy among the facts, to extend the influence of the principle farther than their observations warranted. Such is the character of the human mind. In the same manner have other general principles been on many occasions carried beyond their just limits, till men have been tempted to call their truth or propriety in question, even in instances in which it was absurd to deny it.

SINCE its propagation by Stahl, the doctrine of phlogiston has undergone many modifications. Chemists,

rather unwilling to believe in the existence of an imperceptible material substance, have been anxious to obtain it in a separate state. The discovery of a number of gaseous or aerial bodies, which till within these last twenty years were entirely unknown, naturally excited new hopes of accomplishing so important a purpose. Some of the most respectable British chemists have at length persuaded themselves, that it must be *inflammable gas* which performs that great part which has been assigned to phlogiston. Mr Kirwan, the great patron of this opinion, would have us to believe, that bodies owe to this gas, existing in them in a concrete state, all the properties which they have been said to derive from phlogiston; and that when they are decomposed by combustion, this concrete gas is disengaged from them, and from a concrete reduced into a gaseous or elastic fluid state. To make out his system, he adds to this, that *fixed air*, or carbonic acid, is the principle of acidity. And these, with some other additions, compose a body of theory which he finds means to apply, sometimes naturally, and now and then with a little violence, to all the phænomena which it is the province of chemistry to explain.

BUT the French chemists have treated the system of Stahl with still less respect. Their discoveries have led them to give a very different account of the principle of heat. They are not willing to allow of its existence in a quiet state in combustible bodies; nor do they ascribe to its influence the properties which those bodies lose by combustion. M. Lavoisier and his followers are the French chemists to whom we here allude. He has discovered, that, instead of losing a part of their weight by that process which is thought

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to deprive them of a principle, bodies actually become heavier, by burning, than they were before. It is the surrounding atmosphere, not the burning body, that suffers a diminution. Whatever the levity of phlogiston or inflammable air, or any other principle of terrestrial bodies, it cannot surely be *absolute*. Some bodies, we know, have a tendency to occupy a situation nearer to the centre of the globe; while others recede to a greater distance from it, and give place to those of which the specific gravity is greater. But we do not know, we cannot think, that any bodies or principles of bodies are actually repelled from the centre of the globe, while others are attracted to it. Were the existence of any such to be discovered, it would contradict all our present notions of the laws by which the material world is regulated. But if Stahl's and the other ideas of the existence of phlogiston be just, and M. Lavoisier's experiments at the same time accurate, and the results *faithfully* related, phlogiston must be such a body; for, by losing it, the body to which it is said to have belonged gains an addition of weight;—and by taking it in, the surrounding atmosphere is diminished both in weight and bulk.

THIS is indeed a perplexing fact for the advocates of phlogiston. But if it cannot be denied or explained away, recourse may be had to others, which will strike with no small force against any theory that can be founded on it. In many instances of combustion a new elastic fluid, which did not before exist in the atmosphere, appears to be formed. That elastic fluid is inflammable air, the phlogiston of Mr Kirwan. Now, if not disengaged from the burning body, whence can it proceed?—A subsequent discovery, however, has solved

ved this difficulty. In prosecuting his experiments, M. Lavoisier discovered, that water, which had been always considered as a simple body, was actually a compound consisting of two distinct principles; one of which was the substance which is in certain circumstances rarefied into inflammable gas. And it has been farther discovered, or is at least asserted, that in all those cases of combustion in which inflammable gas is produced, it is supplied by the decomposition of water, or oils, or some other substance in which it exists in combination.

THE experiments to which this last discovery was owing were extremely nice; such, that the utmost accuracy of observation was necessary to distinguish the results. In such cases mistakes are easily made; nay, it is scarce possible to avoid them. Dr Priestley and some other English philosophers were at first disposed to acquiesce in the results of those experiments. Facts may be tortured to support a theory, or explained away: But when they are established, when they force themselves on our observation, the philosopher cannot, without forfeiting his character, shut his eyes against them. But, by repeating the experiments above alluded to in different circumstances, Dr Priestley, whose skill in making experiments and observing the results cannot be doubted, has been since induced to think, that they do not justify the inference that water is a compound body; and that the appearances from which this inference has been deduced, may be more naturally accounted for, by allowing water to be a simple substance, and still admitting the existence of phlogiston in combustible bodies, and its disengagement by combustion. Mr Kirwan, and Mr Keir too, who in these matters

matters may be considered as the disciples and followers of Dr Priestley, eagerly contend in late publications for those modifications of the phlogistic theory which they have adopted. They trace the antiphlogistic principles in their application to all the different facts which chemistry has collected; they find, that the French chemists, notwithstanding all their specious pretences, representing the antiphlogistic theory as being not a theory, but merely a plain statement of facts, often reason by analogy, sometimes venture to indulge conjecture, and even find it necessary, at times, to make a bold assertion, and require us to take what they advance upon their credit. The champions of phlogiston think they may very fairly put on the same arms, and practise the same arts: And they have certainly done both with so much address as to keep the contest still undecided.

M. LAVOISIER, whose name, whatever be the issue of the present controversy, must surely be long respectable in the annals of philosophy, has lately published a small treatise, in which the elements of chemistry are explained on his own principles.

THE method which he follows is different from that which has hitherto been usually adopted by writers on the elements of this science. He begins not with explaining the nature and asserting the dignity of chemistry; nor does he inquire into the number of the elements of nature, or explain the laws of affinity in the introductory part of his book. He is of opinion, that those who are only beginning the study cannot well understand these things, if they attempt to study them in the order in which they are usually laid down.

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His principles, too, render it necessary to follow a new order in explaining the elements of the science.

His work is divided into three parts. In the first, he explains the formation and the decomposition of aeriform fluids, the combustion of simple bodies, and the formation of acids. In the second, he treats of the combinations of acids with salifiable bases, and of the formation of neutral salts. The third part is occupied with an account of the apparatus and instruments of chemistry, and of the manner of conducting chemical processes.

THE reader who is at all acquainted with the principles of this science, will perceive, on taking the trouble merely to compare the contents of this comprehensive work with that of M. Lavoisier's, that scarce any of those things which are explained by M. Lavoisier have escaped the notice of M. Fourcroy. The formation of gaseous fluids, the composition of the atmosphere, the origin of acids, the component principles of water, the various phenomena of heat, the composition of animal and vegetable matters, are explained with no less ingenuity and perspicuity by the latter of these writers than by the former. They have been at equal pains in tracing the radical principles of the acids through all their various combinations; and they are equally careful to render their works intelligible, by exhibiting a comparative view of the new nomenclature which *they* have adopted, with the names of chemical substances which have hitherto been in general use.

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BUT their objects were different. M. Lavoisier confines himself to explain the principles of his own theory, to relate the experiments, and point out the analogies on which it is founded; and to illustrate it by exhibiting a view of such of the doctrines of chemistry as are most happily calculated for that purpose. M. Fourcroy examines all the kingdoms of nature, and gives a complete body of chemical knowledge. The two works differ also in point of arrangement; but each has in this respect its peculiar advantages and disadvantages: And it would not be easy to decide, which of the two plans is most likely to facilitate the study of the science. Perhaps M. Lavoisier's is best calculated to impress the mind of the reader with a favourable opinion of the antiphlogistic theory. But he is almost too artful and too interested an advocate for the beginner to listen to; who wishes, not to enlist under the banner of a party, but to acquire just ideas of the elements of the science, and to distinguish between those truths which are incontrovertibly established, and positions which have, as yet, only probability or plausibility on their side.

THE translator of this work was so much pleased with Lavoisier's book when it came first into his hands, and impressed with such veneration for a name so illustrious in the annals of chemistry, that he formed the idea of enriching his translation of M. Fourcroy's work with a pretty large analysis of M. Lavoisier's. After proceeding so far in the execution of this design as to make out his analysis, with considerable trouble; he found, upon a revival of it, and a comparison of its substance with parallel passages in this work, that it only repeated in a different form what M. Fourcroy had explained with the greatest perspicuity, and even stated in a more im-

Impartial manner. Nay, M. Fourcroy, in his supplementary *Discourse on the Principles of Modern Chemistry*, in the third of these volumes, has actually given a short sketch of the very plan which M. Lavoisier follows. To introduce this work, therefore, with a tedious account of M. Lavoisier's book, would have been merely to swell the size of this first volume, without adding to its intrinsic value. And with whatever complacency he might regard that of which the composition had cost him a good deal of pains; he now saw that it would be impertinent to present that analysis to the public in the honourable place for which he had designed it. He contents himself therefore with mentioning in this general manner the plan of that treatise, and in what respects it differs from, and agrees with, the present work.

If in any Part of his book M. Lavoisier has turned his attention to what has been more slightly noticed by M. Fourcroy, it is in the Third, in which he describes the instruments and the apparatus of chemistry, and explains the methods of conducting chemical processes. But the necessity of plates for the illustration of this part of the work, together with some other circumstances, rendered it equally inconvenient and unsuitable to introduce here any thing from this part, as to give a particular account of the two preceding parts.

THE new nomenclature which M. Fourcroy has now adopted in this work, and which the antiphlogistians wish to establish, will perhaps be regarded rather with an unfavourable eye by the English reader, to whom, even tho'

not a novice in the science, it may probably be a strange language. Objections have been proposed and urged against it; some of them frivolous and capitious, others not without force. Those objections have been made, too, by some of the most skilful and ingenious chemists, who cannot be thought ready to object without reason; and whose voice, in matters respecting the science which they have cultivated, must have authority. Among the most eminent of these are M. Sage and Mr Keir. One of the most plausible of the objections is, that this nomenclature, like others, must be fluctuating: if the principles of the antiphlogistic theory be not in the end established, the nomenclature must be rejected together with the theory: nay, if even any part of its principles shall prove false—and even its authors do not pretend to have demonstrated the truth of every part of it by unequivocal experiments; then must this nomenclature undergo a reformation. Mr Keir seems to be of opinion, it is not easy to see upon what grounds, that it is absurd to propose a chemical nomenclature formed upon principles of analogy, and designed to convey in the names, just ideas of the nature and the composition of the substances. To form such a nomenclature must certainly be an arduous task; perhaps it has not been fully accomplished by the French chemists: but could it be accomplished, it would surely contribute much to facilitate the study of the science. In different departments, the utility of such systems of names has been generally experienced. Must the student of chemistry be denied those helps which have proved so beneficial in other instances? The French chemists have perhaps been in too great haste; it would perhaps be
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advantageous, if they and all the other chemists in Europe would agree to use the same Latin names. But their design is at least laudable; and let us not invidiously deny due praise to their labours.

Of the reasons for a translation of this third edition of M. Fourcroy's work, it is scarce necessary to give an account. They are very obvious. He now appears a convert to the antiphlogistic system; it is only in this edition he uses the new nomenclature: the additions are so scattered through the whole work, that it would be a very unpleasing task for the reader to have recourse to a separate volume whenever they occur to be taken in. These, it is hoped, will be considered as reasons sufficient to justify the present translator in his undertaking, even after the respectable English translations of the two former editions of this work with which the public have been favoured.

THE translator is afraid, that whatever favour the public may be disposed to show to M. Fourcroy's work, they may find reason to consider the present translation as very inferior in its merits to either of the two former, and very unworthy of the original. Yet, whatever labour could do, he has painfully done; he has studied the original with careful attention; and has endeavoured to adhere in his translation to a respectful use of the phraseology appropriated to the science. The road to science, like that to perfection in virtue, is scarce ever found a flowery path; the strict language which must be used in laying down the principles of science, and various other causes which it would perhaps appear petulant to mention, often occasion a degree of heaviness and perplexity in the style of books of science which are very

uninviting. It is not indeed to be expected or wished that the elements of science should be explained in the same airy, lively language in which an agreeable tale is told: but force, and energy, and some degree of vivacity, can have no bad effects. The translator, therefore, while he was studious to express faithfully the sense of his author, wished also to preserve, nay, would have been glad to improve, the energy and liveliness of his style. He is sorry that he cannot please himself with the thought of having fully accomplished what he wished.

It would be very ungrateful were he to neglect mentioning his obligations to the former translations of this work: he read them carefully over; and he hopes he has profited by them.

He has added here and there a few notes, the substance of one or two of which he has taken from the notes to the translation of the second edition; but his notes are so very few, that he will himself confess they do not add greatly to the value of the work. He was indeed deterred from adding many notes, by observing that a considerable part of those with which the translator of the second edition had adorned his pages, contained nothing that was not communicated in different parts of the text. He is afraid that some inaccuracy has slipped into two or three of the numbers in the history of heat; and therefore begs the reader to be on his guard against it, and correct it.

PERHAPS this short view of a few general facts concerning the history and the present state of chemistry, may, as the language in which it is written is loose and

popular, not strictly scientific, be read and understood without much difficulty, and have some small influence in inducing the reader to proceed to a more eager and attentive perusal of the valuable work to which it is prefixed. If it have any such effect, the writer's wish will be fully gratified. The account here given of the circumstances of this translation, and the reasons upon which it was undertaken, the public had a right to expect.

THE Translator of this work, since he has not ventured to bring M. Lavoisier and M. Fourcroy together in these volumes, is very happy to find that such as are disposed to peruse M. Lavoisier's work—and it is certainly well worthy of perusal—may, if they do not choose to study chemistry in French, gratify their curiosity, by having recourse to a very faithful and elegant translation of that work published by an ingenious medical gentleman of this city.

THE HISTORY OF THE
CITY OF BOSTON
FROM THE FIRST SETTLEMENT
TO THE PRESENT TIME
IN TWO VOLUMES
BY NATHANIEL BENTLEY
VOLUME THE SECOND
CONTAINING THE HISTORY
FROM 1700 TO 1780
BOSTON: PUBLISHED BY
J. B. BENTLEY, 1780

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PREFACE TO THE THIRD EDITION,

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NO science was ever more generally or more eagerly cultivated than chemistry has been during these last twelve years: No science ever made such rapid progress in so short a time. These circumstances render a third edition of this work necessary. The second being almost entirely sold off in the space of eighteen months, I have consequently had less time for improving it in a third edition, than I had for improving the first in it. In this edition, therefore, the work is enlarged only with one additional volume; but in the second two were added. Every elementary work, as it passes through successive editions, must at length reach a period at which the judgment of the learned and the discerning will declare farther additions unnecessary; and after which, review and careful corrections will be the only proper means of improving it. I am of opinion, that in this third edition my work has reached that period. An account of the new discoveries since the year 1786 would not have added greatly to the bulk of the volumes: But by the advice of some judicious persons, and in consequence of understanding that beginners found some

difficulties in the perusal of this work, I have been induced to alter and enlarge some chapters in the history of saline matters, of some of the metals, and of several of the immediate principles of vegetable and animal bodies. These new articles, with the new discoveries, of which an account is now introduced in these volumes, are extracted and published as a supplement to the second edition by M. Adet, a young physician, who has been so good as to undertake this task, for which I had not leisure myself. As that supplement comprehends, in a small volume, every thing now added to the second edition, I shall say nothing farther concerning the additions, but confine myself to a few reflections on the progress which the work has made, on the theory which it exhibits uniformly through all its parts, and on the new nomenclature now adopted in it.

WHEN I composed, in the years 1780 and 1781, a short account of the fundamental facts of this science, to serve as a Syllabus to my Lectures; I followed the same plan which I had before adopted in my lectures, and of which some years' experience had taught me the advantages. The unexpected success of that work induced me to follow the same plan in the second edition, published about four years since. The encouragement which the second edition has again received from the proficients in chemistry and the friends of science, and the preference which the rapid sale and the various translations authorize me to say, has been given to it as an elementary book on chemistry through all Europe, induce me still to adhere to the same plan which was laid down in the first edition. To alter my arrangement would have been in some measure to form a new work.

work: yet I don't know but it *might* be altered without any impropriety. Perhaps, the more accurate knowledge which has been gained since the publication of my first edition, the more conclusive reasonings, and the more exact and numerous experiments with which chemistry has, since that time, been enriched, would render it advantageous to arrange the elements of the science in an order somewhat different: To place, for instance, the history of all combustible bodies, sulphur, coal, metals, &c. before that of acids; most of which salts are either burnt bodies, or compounds of combustible bodies. This would be to proceed from simple to compound: the acids of one kingdom would not then be separated from those of the other two kingdoms: only, the differences between the principles of organic bodies and those of minerals would be treated of in distinct chapters. I have marked out a sketch of this method in my Treatise on the Elements of Chemistry, intended for the use of the ladies, and the pupils of the Royal Veterinarian School *.

BUT although, in the present state of chemistry, this last mentioned arrangement of its elements may be preferable; yet that which I at first adopted and still adhere to, is not without its advantages. It requires a little more attention from the student; but even in this instance it is peculiarly favourable to his improvement. It exhibits the same facts in two different lights; it recalls the mind a second time to facts, which have been already exposed to its view; and thus impresses more distinct ideas of the phenomena.

WITH

* School of Medicine of Animals at Alfort, near Paris.

WITH respect to the theory laid down in these elements, this third edition differs essentially from the two former editions. In them, I appeared only as the historian of the different opinions which has prevailed among chemists. But, in this edition, though I still maintain the same impartiality, and give an account of the principal theories which have been proposed; yet I have taken a side, and declared myself an entire convert to that doctrine which has received from some philosophers the name of *pneumatic* or *antiphlogistic*. I flatter myself, that every unprejudiced person who shall carefully peruse these elements, will find that this theory differs essentially from all others that have been hitherto proposed; as it takes nothing upon supposition, admits no hypothetic principle, and consists only in a fair detail of facts. I may even venture to say, that those philosophers who have not yet adopted this doctrine, particularly those who have combated it in some instances with rather too much warmth, have not entered fully into our ideas. They do not see that the ground of our opinions, the foundation on which our principles stand, is totally different from those of other theories which occur in the study of physics. We only deduce plain inferences from a great variety of facts: we admit nothing not demonstrated by experiments: and as we reject every hypothesis, we cannot possibly commit such blunders as those into which the authors of all former systems of physics have fallen. Either I, and those other modern chemists who have produced so many ingenious discoveries, are grossly mistaken; or the rising generation of students, who are taught to reason in a very different manner from their predecessors, will renounce, as we have presumed to do, the hypotheses which have been

so much agitated in the schools, and will confine themselves to the results of fair experiments. A number of celebrated professors have already adopted the doctrine laid down in this work. Messrs de Morveau, Van-Marum, and Chaptal, have been convinced of its truth and simplicity. In order to make himself fully acquainted with this doctrine through all its different parts, and to have an opportunity of comparing it with that which is still maintained by several philosophers, I would advise the student of chemistry to read carefully over the celebrated Mr Kirwan's work upon phlogiston, with the notes and observations which we have added to it. They will find in Mr Kirwan's explanation of the simple facts, a train of hypotheses, truly ingenious indeed, but always in a greater or a less degree forced and inconsistent with the facts which they are adduced to explain; in our application of the same facts, hypothesis is no where introduced.

IN this third edition, I use the new nomenclature which was proposed in the year 1787, by Messrs de Morveau, Lavoisier, Berthollet, and myself. I shall not here repeat the reasons which induced us to make this innovation; the late discoveries and the systematic order introduced into this science in consequence of these rendered it indeed unavoidably necessary. Neither shall I make any reply to those objections, in general exceedingly weak, which have been urged against it; and still less can I think of answering the abusive language and witticisms which have been thrown out by men who had no reasons to offer. I shall only say, that in five courses of lectures which I have delivered since the formation of this nomenclature, I have constantly made use of it, and have found the use of it attended

attended with all the advantages which it was expected to produce. Those who heard these lectures, easily understood this system of names, and entered into the analogies on which it is established. They actually acquired more knowledge from one course, than it was formerly possible for a student to gain by attending three or four, however eager and unremitting his application.

THERE is one among the objections, urged against this nomenclature, to which it may not be improper to call the reader's attention. The words *oxygene* and *hydrogene* are said to be too limited in their significations to answer properly the purposes to which we have applied them; the principle to which we have appropriated the first of these denominations, not always forming acids in its combinations; and the second not being allowed by all philosophers for one of the component principles of water. But, in our treatise on the nomenclature, we have observed, that we do not presume to offer it as a word expressive of the more general qualities of vital air; it would perhaps have been impossible to find a word more generally expressive of its nature, and at the same time suitable to our purpose: such an attempt would have rendered the denomination too vague; and it could not, in that case, have been so distinctly comprehended by the students, as that which we have proposed, and which is taken from one of the most striking characteristic properties of this principle; though a property which it does not exhibit in all its combinations. On the word *hydrogene* we have observed, that it is formed to be precisely expressive of a fact, the result of certain unequivocal experiments; that the body to which we give this name is one of the essential principles of water; and that its necessity

necessity to the composition of its water is one of the most striking of its properties. It is surprising, that it never occurs to the people who repeat such objections against us, one after another, that these, with many others, must have arisen to ourselves, when we were no less than nine months diligently employed on the reformation of the nomenclature. It is surprising that it never occurs to them, that we can find nothing new in the reasonings which they urge against us, after having already often discussed them; and that they have not learned, that all their objections, all their arguments, having been an hundred times proposed, and discussed, and viewed in every light, in our conversations on the subject, at which a number of our learned brethren of the academy obligingly assisted, appeared so trivial in comparison with the advantages likely to be obtained by the use of the new denominations, that we thought we might with good reason overlook them. Those people are to be farther informed, that it was not till after having in vain sought through all the varieties of etymology, for words which might be expressive of the more general properties of these principles, that we gave up the hopes of accomplishing this object. Had we obstinately adhered to our first purpose, we should have introduced into our language a set of harsh and barbarous terms, which it would have been difficult for the understanding to comprehend, or for the memory to retain.

THE only thing that seems to need correction in our nomenclature is the expression *azotic gas*, which might with great propriety be changed into the expression *gas azote*; as has been observed by M. Arejula, a Spanish chemist, who I am proud to number among my pupils,

pupils, and who has published some very judicious observations on our nomenclature. It was certainly an oversight in us to give to the name of this gas a termination different from that of its base, and the same with that in which the names of a whole class of acids terminate; and I, for my part, thank the author for his remarks. In this work, therefore, the reader may, if he think proper, read *gas azote*, instead of *azotic gas*, wherever the latter of these expressions occurs *.

THESE are most of the particulars which I wished to mention to the reader in this place. The great object of this work is to afford as complete a collection as possible of chemical facts in the narrowest compass within which they could be reduced. The science of chemistry is so generally useful to the purposes of human life, that there is reason to expect, that the number of the students of this science will still increase. It is with a view to promote their improvement that I have added in this edition every thing that appeared to me likely to facilitate the study. It is my earnest wish to be useful to them.

* The translator has not ventured to make this alteration; for of innovations there will be no end, if we are thus ready to indulge in them.

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P A R T I.

GENERAL FACTS, *and* INTRODUCTION to the
WORK.

C H A P. I.

*Definition of Chemistry; Chemical Processes; and the
advantages of the Science, &c.*

CHEMISTS are not generally agreed concerning the most proper definition of chemistry. Boerhaave, in his Elements, has ranked it among the arts, or, to speak more accurately, has defined only the practical part of it. Chemistry, according to Macquer, is a science, the object of which is to discover the nature

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and properties of all bodies by means of analysis and synthesis. This definition is indisputably the best that has yet been given. But as analysis and synthesis cannot be employed with equal success in investigating the properties of all natural bodies, it would perhaps be better not to mention them at all when we attempt to define this science. The chemist cannot attain the knowledge of the properties of bodies without bringing them into contact; and as all that he can possibly discover is only the mutual operations of bodies, perhaps the following definition may deserve to be adopted, even in preference to Macquer's: Chemistry is that science which explains the intimate mutual action of all natural bodies*. The facts which we are to relate will illustrate this definition. In order to display the extent of this science in a regular perspicuous manner, we shall consider the subjects upon which it is engaged; the means which it employs; the purposes it pursues; and the advantages which it affords.

§ I. *Concerning the Object, the Methods, and the Intentions, of Chemistry.*

THE subjects on which the labours of the chemist are engaged, are all the substances that compose the globe which we inhabit, whether buried in its interior parts or found at its surface: chemistry is therefore of equal extent with natural history, and the same limits are common to both.

Analysis

* The addition of the word *intimate* seems to obviate the objection offered against this definition by the English translator of the former edition. It distinguishes chemical from mechanical action.

Analysis or decomposition, and synthesis or combination, are the two processes which chemistry employs to accomplish its purposes. The first is nothing but the separation of the constituent parts of a compound substance. Cinnabar, for instance, is a composition of mercury and sulphur; the chemical art analyses it by separating these two bodies from one another. Till of late it was generally thought, and many are still of opinion, that this method is more advantageous in chemical researches than the other. This opinion had even gained such ground among the learned as to induce several of them to define chemistry, The science of analysis. But nothing can be more inconsistent with the just idea of decomposition. In order to set this important truth in a proper light, we must divide analysis into two kinds; the true or simple, and the false or complicated. The true analysis is that by which the component principles of the body decomposed are obtained, without suffering any alteration. The only criterion by which we can distinguish whether this analysis has taken place, is when, by reuniting the simple substances to which the compound body has been reduced, we can form a new compound precisely similar to the former. Cinnabar will again furnish an instance. When the two substances of which this composition is formed, namely mercury and sulphur, are separated by a chemical process, they are found to be in a state of purity similar to that which they possessed before their separation; for by uniting them we can form a new body, differing in no respect from the original cinnabar. But unfortunately for the science, this kind of analysis can seldom be effected. Chemists are not so happy as to be able to apply it to many of the

bodies on which they make experiments. The neutral salts, and a few other mineral substances, are the only bodies in nature susceptible of this species of decomposition.

The false or complicated analysis is that by means of which a body is resolved into principles different from those which appeared to exist in the composition, and incapable of forming, by their reunion, a body similar to that from which they were obtained.

This kind of decomposition takes place in most of the bodies that are subject to a chemical analysis; no other condition being requisite, but that more than two principles enter into the combination to be examined, and that they be united by a certain degree of mutual affinity. Many minerals, and all vegetable and animal substances without exception, admit of no other species of analysis. Thus sugar, distilled in a retort, affords an acid, an oil, and a coaly residue; but all attempts to recombine these into the same substance from which they were obtained, are uniformly fruitless. This kind of analysis cannot enable us to discover in what state substances existed together in any combination before being separated; and it therefore affords but little useful information, and is not to be trusted without the greatest caution. By trusting too hastily to results of this kind, chemists have afforded room for all that censure to which their art has been exposed. On this account has chemistry been accused of absolutely destroying bodies in its attempts to separate their component parts; and we cannot but acknowledge that the censure was for a long time just: but becoming more circumspect in proportion to her progress, chemistry now rejects that deceitful

ceitful analysis to which she formerly had recourse, and possesses the means of examining the properties and distinguishing the component principles of bodies, without destroying their nature. She even proceeds farther, and, as we shall have occasion to mention more particularly when we come to treat of vegetable substances, estimates the mutual action of principles, and determines by what causes they are thus modified and changed.

Synthesis or composition, the second method of prosecuting chemical inquiries, is the formation of a compound by the artificial reunion of several principles. Its utility, its extent, and the dependance that may be placed on the results which it affords, render it much more valuable than the other: nay, not even a single operation in chemistry can be conducted without producing some new combination. Chemists appear not to have been sufficiently sensible of its importance. In fact, as synthesis is both more frequently employed and more highly useful than analysis, chemistry might be, with a good deal of propriety, represented as the science of combination, not of analysis.

These two methods are sometimes employed separately, but oftener together. It frequently happens that a true analysis cannot be effected without the help of some combination. False analyses are always accompanied with new combinations by synthesis; nay, composition itself often produces a kind of analysis. The last of these facts, however, has been but lately discovered. The discovery of a great number of aeriform fluids, the existence of which was not formerly so much as suspected, has shown that in many operations which were considered as simple com-

binations, an invisible elastic fluid is disengaged with effervescence, and either escapes into the atmosphere, or is received in vessels which have been ingeniously contrived to confine it. Most of the combinations of two principles which were before thought to be simple substances, exhibit this kind of analysis. We shall have occasion to give frequent instances of it when we come to treat of neutral salts.

From this short account of the analysis and synthesis of the chemists, it appears that the whole art of chemistry consists in promoting the intimate mutual action of bodies, and in observing carefully the phenomena with which it is attended. It is to be remembered, that Nature herself constantly employs these two methods, and that from her the chemist first learned to use them. As they depend on the mutual affinities of bodies, all that the artist can do is to dispose these in such a manner that they may act upon each other. The young chemist ought carefully to acquaint himself with these important truths: for these, with the rest to be explained in the following chapters of this first ~~part~~, form the basis of the science.

Hence it is very easy to comprehend the final intention of chemistry. That cannot be merely to discover the first principles of bodies; for there are many substances which cannot be resolved into others more simple, and whose component principles are therefore unknown: yet these substances, though not susceptible of analysis, admit of combination, and act upon other bodies; and therefore it appears evident, that the chief design of chemistry is to discover the mutual actions of natural bodies, to distinguish the order of their combinations, and to estimate the strength of that mutual attraction

attraction which gives them a tendency to unite and to remain in union.

§ II. *Concerning the useful Purposes to which Chemistry may be applied.*

A PARTICULAR treatise would be necessary to give a full view of all the advantages which mankind derive from this science. As the design of this work does not admit of our entering minutely into that subject, we will content ourselves with exhibiting its outlines; insisting, however, more particularly on such of them as appear not to have been hitherto considered with all the attention which they deserve.

Chemistry is beneficial to so many of the arts, that we may arrange them all under two divisions: the first, comprehending all the mechanical arts which depend on geometrical principles; the second, including all those which depend upon chemistry, and therefore merit the name of chemical arts. These last are much more numerous than the other. As they are all founded on chemical phenomena, it is easy to see that the practice of them ought to be regulated by the rules of chemistry; which, by new discoveries, simplifies the processes, renders their success more certain, and even extends the limits of all the arts dependant upon it. These are, 1st, The arts of making bricks, tiles, china, porcelain, and the other species of earthen ware; all of which are preparations of different kinds of clay, baked into different forms, and exposed to the action of heat till each acquire its proper degree of hardness.

2dly, The art of making glass; which, by combining a vitrifiable earth with a saline substance, produces a new body, hard, transparent, and almost impregnable by the action of the air: A wonderful art, from which mankind have derived many important advantages!

3dly, The arts of extracting metals from their ores, of casting, of purifying, and of allaying them by mixture, owe also their origin and progress to chemistry, which is daily throwing new light upon them.

4thly, The vegetable kingdom affords materials to a great number of arts, which, as well as those above mentioned, belong to the province of chemistry. The arts of converting saccharine juices, or farinaceous substances, into vinous liquors; of extracting from those liquors the ardent spirit which they contain; of separating that spirit from the water with which it is at first combined; of uniting this ardent spirit with the aromatic parts of plants; of extracting the colouring matter of plants, and applying it so as to tinge stuffs; and, lastly, the arts of converting wine into vinegar, and combining vinegar with various substances; of separating from grain and other parts of vegetables that precious substance of which we form bread; and of converting so dry and insipid a body as meal into a light, digestible, and pleasant substance; all these arts, and many more, which our present limits allow us not to take particular notice of, belong to the province of chemistry, and are indebted to that science for their present perfection, and in many instances for their first invention.

It has equal claims to all those arts which are employed on animal substances. Such is the useful and too little valued art of cookery; the true end of which is not to flatter the palate, or to va-

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ry the forms and flavours of meats, for the gratification of capricious taste; but to render aliments easy of digestion, by means of boiling, or by applying to them mild and natural seasoning. Hat-making, and the dressing, tanning, and currying of leather, belong to the same class of arts. But one of the most valuable of all the arts, which indeed occupies a middle rank between the arts properly so called and the sciences, and to which chemistry is singularly useful, is pharmacy. Every person concerned in pharmacy needs a very extensive knowledge of chemistry, that he may not be ignorant of those alterations to which the bodies he makes use of are subject; may know how to prevent or correct such alterations; may be called to discover the changes which compound medicines undergo; and, in a word, may foresee readily the combinations or analyses that may be produced by the mixture of any simple drugs. Every impartial person must agree, that to acquire a competent skill in pharmacy, the student ought, after acquainting himself with the natural history of materia medica, to turn his attention to chemistry, and study it with the most earnest assiduity. By these means only can pharmacy be practised on certain principles, so as to render mankind those important services which intitle it to the high rank it holds among the arts.

A very cursory view of the sciences will be sufficient to convince us what important benefits they may derive from chemistry. To natural history it is peculiarly beneficial. The earlier naturalists employed the physical properties of colour, form, and consistency, &c. as the distinguishing characteristics of minerals: but those properties being very liable to variation, the bodies of which ancient philosophers have spoken

spoken are no longer known, and their discoveries are almost totally lost. The moderns have become sensible, that, in order to obviate this inconvenience so fatal to the progress of natural history, some new method must be adopted. Chemical analysis has been thought the happiest that can be employed; and by this method such progress has already been made, that minerals are now ranked into classes according to the nature and quantity of the principles of which they are composed. The progress made in this branch of natural history is owing to the labours of Messrs Bergman, Bayen, Monnet, &c. Wallerius, Cronstedt, and some other naturalists, first began the arrangement of mineral bodies according to their chemical properties. M. Bucquet, in his latter courses of lectures, had improved on the ideas of those two celebrated naturalists; and his mode of arrangement was entirely chemical. M. Sage, who has analysed a great number of minerals, has also employed a chemical mode of arrangement: and tho' no chemist has adopted the whole of his theory, yet mineralogy owes him the highest obligations; and few in France have pursued the study with more industry and success. M. Daubenton has availed himself of the labours of all his contemporaries and predecessors; examining them, however, with a degree of caution worthy of the true philosopher, whose proper object is to discover truth amid that maze of error and uncertainty, in which, unfortunately for mankind, it is too often concealed. Nothing, then, can be more certain than the utility of chemistry to natural history; it affords the only means of removing that obscurity and uncertainty which must ever attend simple descriptions of natural objects. One observation of M. Daubenton merits the particular attention of all chemical philosophers:

phers: He advises them to describe carefully the specimens on which they make their experiments, in order that they may be generally understood by naturalists, and may avoid that confusion which, according to this celebrated professor, prevails through the works of many modern chemists. The only means which I have found proper for avoiding that confusion, is, to connect the two sciences in my lectures, by uniting physical descriptions of bodies with an account of their chemical properties.

But the world are not so generally convinced of the usefulness of chemistry in medicine. The errors of the chemical physicians of the last century, and the indifference of a number of medical practitioners for this science, have impressed many with an unfavourable opinion of it, which time alone can remove. Yet, it would surely be better not to lend an ear to the voice of prejudice, but to inquire candidly into the causes of those mistakes which chemists have committed, and to consider by what means they may be for the future avoided, and the science restored to its just honours. Though the first physicians who cultivated chemistry were misled by a blind enthusiasm; yet from that no inferences can be drawn applicable to the chemistry of the present time. The precision which the moderns have introduced into every part of experimental philosophy, cannot but remove all the apprehensions which might be entertained, if chemistry were still involved in the same degree of mystery and obscurity in which it was a century ago. If employed with caution, and with a due regard to the extent of its powers, it cannot but be highly beneficial to medicine. After thus acknowledging the whims and blunders of chemists, let

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us proceed to justify the science, by examining how far it is useful to every branch of medicine. Let us first distinguish between the two great departments of this extensive science, namely, the theory and the practice; which, however, ought not to be entirely separated from each other, as they have been by some authors. The study of medicine ought always to begin with the anatomy of man and the other animals. But the solids are the only part of the animal frame subject to the examination of anatomy; while it is well known to physiologists, that the greatest part of animal bodies consists of fluids, by the motion of which life is maintained. Were we then to confine our observation to the structure of the vessels, without examining the nature and properties of the fluids which they contain, we should be acquainted with only one part of the animal system. It is the business of chemistry to explain to us the qualities of these fluids: chemistry affords the only means by which we can acquire a knowledge of the principles of which they are composed, and of the changes which they undergo in performing those functions by which they contribute to the support of life. Without the aid of this science, it would be impossible for us to discover the mechanism of the animal functions; to distinguish between the various fluids separated by the different viscera; to observe what alterations these suffer when collected in their several reservoirs; or to understand how they are affected by heat, cold, or mixture with other fluids, &c. When we are thus far acquainted with the composition of animal fluids, it will next be proper to examine what variations they are liable to, from differences of sex, age, constitution, climate, and season; and

and to trace them through the various species of animals: thus shall we establish certain points of comparison, by means of which the limits of science may be extended. It is not enough, however, to examine the chemical properties of the animal fluids when the system is in a sound state: they should be observed with no less attention when the body languishes under disease, in order that it may be certainly discovered what alterations they suffer in the various distempers to which the human frame is liable; what part of the humours predominates in putrid, inflammatory, scorbutic, or scrophulous disorders; what saline combinations are formed during the progress of the distemper; what matter extruded from its proper vessels. Such researches cannot fail to make physicians better acquainted with the history of pathology. We think it equally necessary to examine the solids by chemical methods, in the sound as well as in the diseased state of the body; that by considering their properties, we may discover from what fluid they are produced; and, this known, may conjecture upon good grounds, what solid or fluid has suffered alteration in any distemper. This position, which is here but slightly mentioned, will be more particularly explained in the chapters on Animal Matters.

But chemistry is no less useful to the practice than to the theory of medicine; nor can it indeed be useful to the one without promoting the other at the same time. It will, therefore, be no difficult task to show the dependance of the practice upon this science. To begin with the art of preserving health; an accurate chemical knowledge of the various articles of food, and of the atmospheric fluid, is necessary to enable us to make a proper choice of air and aliments. By chemistry

mistry we learn what quantity of nutritive matter is contained in every different article of food ; in what particular state that matter exists in each of the bodies in which it is found ; the nature of the several substances with which it may be combined ; and the means of extracting, purifying, and preparing it in a manner suitable to the strength or weakness of different stomachs. It is the same science that explains to us the nature of those fluids which we use for drink ; what properties render water wholesome or noxious, and how to separate from it whatever may render it injurious to the animal œconomy ; what are the principles of fermented liquors, and in what proportion those are mingled together in the several kinds of wine ; as also by what processes we may distinguish whether wine is genuine or adulterated : Lastly, by the same means we learn, what properties render air fit for respiration ; to what changes that fluid is liable ; and what other substances are capable of altering its purity, by entering into combination with it. Chemistry likewise supplies us with the happy means of correcting the qualities of air when noxious, so as to restore it to that state in which it is proper for respiration : for the discovery of which means we are indebted to the industry of the moderns, as shall be shown in the History of Air.

The physician ought not to make use of medicines unless he knows their nature ; and that knowledge he must learn from chemistry. This has been so long generally acknowledged, that the writers of the *materia medica* arrange medicines by their chemical properties. The uniform experience of all ages has established it as a certain truth, that there is a close and natural relation between the taste of bodies and the manner
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in which they act on the animal œconomy ; so that by tasting any substance we may judge of its medicinal qualities : Bitters are stomachic ; insipid substances, mild and relaxing ; bodies of an agreeable sweet taste, nutritious ; acid substances, active, penetrating, and incisive. But as taste is undeniably a chemical property, depending on the tendency of substances to combination, as shall be elsewhere shown, we must confess ourselves indebted to chemistry for whatever knowledge of the properties of bodies we can gain by examining their taste : Yet it would be absurd to suppose, with the chemical physicians of the last century, that the stomach is a vessel in which chemical processes are carried on, as in a laboratory. The intestines possess indeed sensibility and a peculiar motion, which modify the nature and operation of such medicines as are administered ; but it becomes the physician to repress those wild sallies of imagination which lead to ridiculous hypotheses, and to admit only such facts as are established by accurate observation. It cannot be denied, that, in some cases, medicines act in the first passages by means of their chemical properties : then, indeed, the physician may apply his chemical knowledge. Long experience has shown, that in the diseases peculiar to children, the stomach and intestines are coated with a tenacious viscous matter, which is manifestly of an acid nature. The absorbent earths, and alkalis administered on such occasions, destroy this acid by entering into combination with it, and form a neutral purgative salt, which by stimulating the intestines, causes them to evacuate the noxious matter. All diseases that occasion an accumulation of obstructive matter in the primary passages, require the physician to possess some chemical knowledge ;

ledge; as it is certain that some substances will act with more force than others on that obstructive matter. Thus, for instance, acids may be administered to remove one kind of obstruction, and solutions of salts for another.

But the greatest advantage which the practitioner of medicine can derive from chemistry, is on those alarming occasions when, by accident or design, some of those corrosive substances have been swallowed, which prove fatal to life by attacking the viscera, and destroying their organization. On such occasions chemistry lends the readiest and most effectual aid to medicine, by supplying substances which have power to decompose the poison, and by that means obviate its direful effects. Navier, a celebrated medical chemist of Chalons, has published a work, in which he points out effectual remedies to prevent the destructive effects of the poisons of arsenic, corrosive sublimate, verdegriis, the preparations of lead. Notwithstanding the angry declamations of some physicians, who seem desirous of excluding the sciences from the practice of medicine, his work well deserves the gratitude of posterity. Not only does chemistry at present enable us to counteract effectually the operation of mineral poisons; but there is even reason to hope, that careful inquiries into the nature of animal and vegetable poisons, may enable us to discover some substances capable of divesting them also of their pernicious powers. Opium, and all narcotic vegetables, the acid and caustic juices, such as those of spurge and euphorbium, the noxious plants, particularly mushrooms, are all well worthy of the particular attention of the chemist; as by his researches some means may possibly be discovered which may render them no longer equally

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dangerous. It is of no less importance to examine the nature of animal poisons. From the experiments of Margraaf and Fontana we are already acquainted with the acid of ants: Thouvenel has discovered several acrid substances in cantharides: Mead has examined the venom of the viper: Fontana has pursued a train of observations on the same poison; and has discovered, that the *lapis causticus*, introduced immediately into the wound made by this reptile, decomposes the poison, and prevents its effects.

Though chemistry were not to contribute so much in these instances to the benefit of medicine; yet still by supplying such a number of valuable drugs, she must be confessed to render services of the highest importance to this useful science. Stibiated tartar, together with the various mercurial, antimonial, and martial preparations, which are so often and so successfully prescribed, when considered as the gifts of chemistry, must surely induce physicians to esteem the science, and to encourage those who prosecute chemical researches from a desire to contribute to the advancement of medicine. As for myself, the natural bent of my genius, no less than my particular situation, leads me to cultivate both sciences with the most earnest wishes to promote their improvement. The declamations of those, who from their ignorance of chemistry, are induced to represent it as of no utility in medicine, shall never detach me from this science. I have engaged with ardour in the study of animal chemistry, and am determined to follow the steps of those who have already prosecuted it with so much success.

To conclude our observations on the utility of chemistry to medicine; we shall only add, that a certain degree of chemical knowledge is absolutely necessary

to enable the physician to make out a prescription of any compound medicine, to be prepared by the apothecary. Persons unskilled in chemistry are liable to commit the grossest blunders daily in making out prescriptions; to order, for instance, the composition of substances incapable of subsisting in union, or which have a mutual tendency to decompose one another. In the case of decomposition, the medicine administered cannot possibly produce the desired effects. Chemistry furnishes the only means to prevent such blunders; which are often attended with the most unhappy consequences. If possessed of chemical knowledge, we will never attempt to compound together substances incapable of mutual combination; the laws of chemistry must always direct us in the preparation of compound medicines. Without a knowledge of chemistry, the physician must ever be liable to commit numerous blunders; which, though they should be followed by no other bad consequences, cannot but expose him to the contempt of the apothecary; as the practice of the apothecary naturally makes *him* acquainted with many chemical facts.

The usefulness of chemistry in the arts, and the resemblance of its processes to the manipulations of artists, have caused it to be confounded sometimes with alchemy, sometimes with pharmacy; though *they* must be very ignorant indeed, who can thus confound objects so widely different from one another, and can regard the chemist as a fanciful projector, unweariedly employed in a vain search for the philosopher's stone. Even a very slight attention to the nature and pursuits of chemistry, may be sufficient to convince any person that there is a vast difference between those purposes
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which the chemist pursues in a train of regular connected researches, and the transmutations which the alchemist pretends to effect by a set of absurd and desultory processes. That mistake which leads many people to regard chemistry as the art of preparing drugs is more excusable; it confounds not the chemist with the ignorant and insignificant operators of the Great Work; who, as is humorously observed by Macquer, are the artisans of an art which has no existence; but associates him with a class of useful and respectable artists, whose labours are of high importance to society. Yet as pharmacy is but one branch of chemistry, to confine chemistry to the making up of medicines, is to entertain a very unjust idea of the extent of the science. Pharmacy, as well as all the other arts dependant on chemistry, is guided and assisted in its operations by this science. But chemistry, in its nature and objects, is more sublime and extensive; it extends its inquiries and inductions to the reciprocal action of all the bodies in nature; and thus contributes at the same time to the advancement of both philosophy and the arts.

C H A P. II.

The History of Chemistry.

THE student of any science should make himself acquainted at least with the outlines of its history. A knowledge of the leading facts, and of the dates of different discoveries, will be of use to enable him to avoid the errors of those who have preceded him in the same pursuits, and to direct him to the path which leads to improvement. But as a very minute detail of the history of chemistry might possibly be considered as an unnecessary digression from the main object of this treatise, we shall confine ourselves to a view of leading facts, without entering into particulars. Whoever is desirous of fuller information concerning the rise and progress of chemistry, may consult a variety of well-written works which have been published on the subject; particularly, the Treatise of Olaus Borrichius, *de ortu et progressu Chemiæ*; the article *Chimie* in the *Dictionnaire Encyclopedique*; the Introduction to Senac's Treatise on Chemistry; Abbé Lenglet du Fresnoy's History of the Hermetic Philosophy; the first chapter of Boerhaave's Chemistry; and the Discourse prefixed to Macquer's Chemical Dictionary, &c.

To

To give the reader a brief and methodical account of the progress of the human mind in the study of chemistry, and of the successive discoveries which have been made in this science; we shall divide our history into six periods.

I.

The Origin of Chemistry among the Egyptians, and its progress among the Greeks.

THE origin of chemistry is hid in the same obscurity which conceals that of the other arts and sciences. The patriarch Tubal-Cain, who lived before the flood, is considered as the inventor of chemistry; but the only part of it known to him was the art of working metals: he seems to have been the same with the Vulcan of fabulous history.

We may with more confidence ascribe the invention of this science to the ancient Egyptians. According to Abbé Lenglet du Fresnoy, Thoth or Athotis, surnamed Hermes or Mercury, is the first of this nation of whom mention is made as being a chemist. He was the son of Mezraim or Osiris, and the grandson of Cham. He became king of Thebes.

Siphoas was the next Egyptian monarch, who was also distinguished as a philosopher. He lived 800 years after Athotis, and 1900 before Jesus Christ. He is named Hermes, or Mercury Trismegistus, by the Greeks; and is therefore the second Mercury: he is considered as the inventor of natural philosophy; he wrote two and forty books on the subject of philosophy, the titles of which have been handed down to us by various historians.

storians. None of them seems to have treated directly of chemistry; though from him has the science been intitled the Hermetic Philosophy.

We know but little concerning those who cultivated chemistry among the Egyptians; but the science appears to have made considerable progress among them, for they practised many of the arts dependant on chemistry; particularly the arts of forming imitations of the precious stones, of casting and working metals, of painting upon glass, &c.: but the chemistry of this ancient people has been lost, as well as their other arts and sciences. The priests involved them in mystery, and concealed them under the veil of hieroglyphics. Alchemists have persuaded themselves, that some vestiges of their pretended art may be traced among the remains of the Egyptian hieroglyphics; and that the temple which the Egyptians dedicated to Vulcan was erected in honour of alchemy.

The Israelites acquired a knowledge of chemistry from the Egyptians. Moses is considered as a chemist, on account of his dissolving the golden idol which the people had set up. It has been thought, and Stahl has even written a dissertation to prove, that he rendered the gold soluble in water by means of liver of sulphur. Such a process supposes a pretty extensive knowledge of chemistry.

Democritus of Abdera, who lived about 500 years before Jesus Christ, travelled into Egypt, Chaldea, and Persia, &c. and is said to have gained some skill in chemistry in the first of those countries. Though the son of a man whose opulence had enabled him to entertain Xerxes and all his attendants, he returned very poor to his native country, where he was kindly received, however, by his brother Damassus. Retiring to

a garden near the city-walls of Abdera, he employed himself in the study of plants and precious stones. Cicero asserts, that Democritus, in order that he might not be diverted from his speculations by external objects, deprived himself of sight by gazing on the rays of the sun reflected from a vessel of polished copper : But Plutarch denies this fact. Pliny was so amazed at the knowledge of Democritus, that he considered it as quite miraculous.

Several authors reckon Cleopatra a chemist, because she knew how to dissolve pearls. It is even affirmed, that the art of chemistry being known to all the Egyptian priests, continued to be practised among that nation till the time when, according to Suidas, Dioclesian thought to reduce them more easily under subjection, by burning their books on chemistry.

II.

The Chemistry of the Arabians.

AFTER a long series of ages, through which it is impossible to trace the progress of chemistry amid the revolutions of empire ; this science again appears among the Arabians, and cultivated so successfully as to merit our attention.

Under the dynasty of the Achemides, or Abassides, the sciences, which had long been neglected, regained their former vigour. Almanzor, the second Caliph of that family, eagerly cultivated astronomy. Harun Raschid, the fifth caliph, who was cotemporary with Charlemagne, caused several books on chemistry to be translated from the Greek into the Arabic.

In the ninth century, Gebber of Thus, in Chorazan, a province of Persia, wrote three different treatises on chemistry; which contain a number of tolerably good things. His masterpiece is intitled, *Summa perfectionis magisterii*. He has written with considerable perspicuity on distillation, calcination, the reduction and the solution of metals.

In the tenth century, Rhazes, physician to the hospital of Bagdad, first applied chemistry to medicine. Some of his pharmaceutic prescriptions are still in esteem.

In the eleventh century, Avicenna, a physician, in imitation of Rhazes, applied chemistry to medicine. His merit raised him to the office of Grand-Vizir; but his debaucheries occasioned his degradation from that office.

III.

Chemistry passes from the East to the West, in the time of the Crusades.

THE art of making gold continued long in repute, according to the authors who have written upon it. But the madness that gave rise to it rose to its greatest height between the eleventh and the sixteenth century. The chemical facts which had been discovered by the Egyptians, collected by the Greeks, and applied to medicine by the Arabians, became known to the four nations who visited the east in the Crusades; and England, France, Germany, and Italy, soon swarmed with a set of men eager in search of the philosopher's stone. As their labours contributed to the advancement of chemistry,

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chemistry, it is but reasonable to take notice of some of the most distinguished among those singular geniuses.

In the thirteenth century, Albert the Great, a Dominican of Cologne, and afterwards of Ratibon, was reputed a magician; and composed a work, which contains descriptions of many alchemical processes.

Roger Bacon, born in the year 1214, near Ilchester in the county of Somerset, studied at Oxford, and came afterwards to Paris to prosecute his studies in mathematics and medicine. He is celebrated as the author of several inventions; any one of which might well intitle him to immortality. Among these are the camera obscura, the telescope, and gunpowder. He is said to have made a self-moving chariot, a flying machine, a speaking head, &c. He was a cordelier, and was surnamed the *Admirable Doctor*. Being accused of magic, his fellows were obliged to imprison him. He afterwards resided in an house in Oxford, where he is said to have worked in alchemy. Borrichius saw the house, which was still known by his name*.

Arnold of Villeneuve, born in Languedoc in 1245, died in 1310, having studied medicine at Paris for 30 years. He wrote a commentary on the *Schola Salernitana*. The alchemists respect him as one of their greatest masters. Borrichius, in the year 1664, saw one of his descendants, an alchemist, in Languedoc.

Fourteenth century. Raymond Lully, born in Majorca in 1235, came to Paris in 1281; where he became acquainted

* Concerning this house, if I mistake not, a tradition has been long known at Oxford; that when a greater man than Roger Bacon passes beneath it, it will tumble down upon his head. It stands on a bridge.

"And Bacon's mansion trembles o'er his head." JOHNSON.

acquainted with Arnold of Villeneuve, and studied under him. Robert Constantine relates his having seen in the Tower of London a Rose Noble struck out of gold, made by Lully, under the reign of Edward V. in the years 1312 and 1313. He has left several books on alchemy, which contain some facts relative to the preparation of acids, or strong waters, and the properties of metals.

Fifteenth century. Basilius Valentinus, a Benedictine of Erfort in Germany, was skilled in medicine and natural history. He has left a work on antimony, under the pompous title of *Currus triumphalis Antimonii*, on which a commentary has been written by Kerkringius. That book describes a considerable number of antimonial preparations, which have been since offered to the world as new discoveries, under different names, and have been prescribed with great success for several disorders.

The two Isaacs of Holland, father and son, though but little known, have left some treatises which are praised by Boerhaave, and from which they appear to have been acquainted with aquafortis and aqua regia.

All these authors have written on chemistry in a very obscure, confused manner. Though acquainted with some processes of solution, extraction, and purification, &c. their pretensions rose much higher than their knowledge; and scarce any advantage can be derived from a perusal of their works.

IV.

The universal Medicine ; Pharmaceutic Chemistry ; Alchemy opposed, from the sixteenth to the middle of the seventeenth Century.

THOUGH the vain projects of the alchemists had been invariably unsuccessful, and had been almost always attended with the loss of fortune and reputation ; yet, in the sixteenth century, a prodigious number appeared, at the head of whom was Paracelsus a Swiss physician, born at Zurich in 1493, whose reveries were eagerly embraced by the rest. That fanciful man asserted, that there was an universal medicine, and substituted chemical preparations in the place of the Galenical pharmacy then in use. He cured many diseases in which the ordinary remedies had been ineffectually applied, and particularly venereal complaints with mercurial preparations. He performed some very surprising cures ; but became so extravagantly flushed with his success, as to burn in public the writings of the Greek physicians. He died amid his imaginary triumphs in an inn in Saltzburgh, at the age of 48, after having promised himself immortality from the use of his secrets.

Notwithstanding the extravagance and absurdity of his idea of an universal medicine, it attracted the attention of alchemists, and revived the spirit of alchemy. Several imagining that they had discovered the universal medicine, assumed the new title of *Adepts*. Among those were, at the beginning of the seventeenth century,

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1. The Rosicrucians, a fraternity that arose in Germany, were never known but by name in France, and whose individual members never made any public acknowledgment of their principles. They pretended to be in possession of the art of transmutation, the universal science, the universal medicine, and the science of occult things, &c.

2. A wandering fellow, named Alexander Sethon or Sidon, who is said to have performed the work of transmutation in Holland, in the presence of a person of the name of Haussen. Haussen related the fact to Vander Linden, grandfather to the physician of that name, who collected a medical library.

3. Another named Thomas Vaughan, born in England in 1612. He went to America, where Starkey saw and received gold from him. Boyle corresponded with him. This is the same adept who, in France, gave his powder of projection to Hevelius. The latter, in consequence of this pretended miracle, which was nothing but a trick, wrote a dissertation *De Vitulo aureo*, &c.

Yet the success with which Paracelsus had prescribed his chemical medicines, induced a number of physicians to cultivate that new art; and in a short time several valuable works appeared on the preparation of chemical medicines. Such are the works of Crolius, Schroder, Zwelfer, Glafer, Tackenius, Lemery, &c.; as well as the pharmacopœiæ published by the principal faculties of medicine in Europe. About this time Glauber, a German chemist, rendered an important service to his art, by examining the residues of operations, which had hitherto been always thrown aside as useless, and distinguished by the name of *caput mortuum*, or *terra damnata*. He discovered by this means

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the neutral salt which bears his name, and the ammoniac vitriolic salt, and explained the chemical processes necessary in preparing mineral acids, &c.

Several of those who have contributed to the advancement of chemistry since the days of Paracelsus, were not fully convinced of the absurdity of his wild notions. Among those were Cassius, known for his precipitate of gold; Sir Kenelm Digby, who believed in the sympathetic action of medicines; Libavius, who has communicated his name to a preparation of tin; Van Helmont, famous for his singular notions both in chemistry and medicine; and, lastly, Borrichius, a Danish physician and chemist, who first discovered and made known to the world the possibility and the manner of inflaming oils with the nitrous acid, and who deserves the gratitude and respect of the world for having bequeathed his library and chemical laboratory for the use of indigent students of medicine.

Alchemy was now opposed by two celebrated geniuses, who were successful in their attacks. The one, the celebrated Father Kircher the Jesuit, to whom we are indebted for a noble work, intitled *Mundus Subterraneus*; the other, the learned Conringius.

V.

Rise and Progress of philosophical Chemistry, from the middle of the seventeenth to the middle of the eighteenth Century.

HITHERTO chemistry had never been treated in a philosophical manner. The chemical arts had indeed been described, medical formulæ had been given, and

the nature of metals painfully examined, from the hope of making gold, or discovering an universal medicine. A chimera still fondly believed by the ignorant and enthusiastic! But nothing more had been done. A great number of chemical facts were known; but none had attempted to form them into a system. And, as the celebrated Macquer has ingeniously observed, though many branches of chemistry were known and practised, the science itself was not yet in existence.

Towards the middle of the seventeenth century, James Barnet, physician to the King of Poland, arranged the principal facts then known in a methodical manner, accompanying them with observations, in his *Philosophy of Chemistry*. The work of that learned author is the more valuable, on account of his being the first who attempted to form a complete system of chemical knowledge, and ranked chemistry among the sciences.

Bohnius, professor at Leipzig, wrote also a book on scientific chemistry, which was very favourably received by the world, and was long the only elementary book on the subject.

Joachim Beccher of Spire, a man of very considerable genius, physician to the Electors of Mayence and Bavaria, distinguished himself so highly in this science as to cause the names of the two last mentioned writers to be almost entirely forgotten. In his noble work, intitled *Physica subterranea*, he has collected all the chemical phenomena at that time known, and has described them with amazing accuracy. He has even foretold many of the discoveries which have been successively made since he wrote; such as the existence of aeriform or gaseous substances; the possibility of reducing animal bones into a transparent glass, &c.

A celebrated physician, whose name marks the commencement of a new and more illustrious æra in the annals of chemistry, has done him the honour of writing a commentary on his work. J. Ernest Stahl, who was born with a natural fondness for chemistry, undertook to illustrate the doctrine of Beccher by a commentary. His favourite object, to which he more particularly directed his attention, was to demonstrate the existence of that inflammable earth which he denominated Phlogiston. Not inferior to Beccher in genius, he excelled him in accuracy and method. His treatises on sulphur and salts, together with that which is intitled *Trecenta Experimenta*, have acquired him immortal honour, and have ranked him among the first characters of the age in which he appeared.

Boerhaave, amid his various engagements, found leisure to cultivate chemistry, and composed a very profound work on this science, which has long been highly celebrated. The treatises on the four elements, particularly that on fire, which form a part of that work, are each of them masterpieces, containing all that was at that time known on their particular subjects. He was also the first who attempted to analyse vegetables; and to him we owe the spiritus rector, &c.

Stahl's theory has been generally adopted by succeeding chemists, and has acquired greater stability from the labours of the two illustrious brothers Messrs Rouelle, to whom we are chiefly indebted for the progress which chemistry has made in France, and whose loss is severely felt by the chemical world.

The illustrious Macquer, of whom death has now deprived the philosophical world, contributed in a very signal manner to the advancement of the science; and

and his valuable works are still justly esteemed, over all Europe, as the best guides to chemical knowledge. Besides the important services which he performed to the world, by publishing his Dictionary and Elements of Chemistry, his inquiries and discoveries concerning the nature of arsenic, Prussian blue, the dying of silks, clays for pottery, &c. might well immortalize his name, and intitle him to the gratitude of posterity.

VI.

Pneumatic Chemistry: the present Time.

STAHL, being totally engaged in demonstrating the existence of phlogiston, and tracing it through all its combinations with other bodies, seems to have overlooked the influence of air in most of those phenomena in which he ascribes so much to the energy of the inflammable principle. Boyle and Hales had already shown the necessity of referring many chemical phenomena to the operation of that fluid. Boyle had taken notice of the different appearances which the same chemical events exhibit in the open air and *in vacuo*. Hales had obtained from a variety of bodies a fluid which he took for air, but in which he observed a number of peculiar properties; such as smell, inflammability, &c. according to the nature of the substances from which it was obtained. He was led to consider air as the principle on which the consistency and solidity of bodies depended.

Dr Priestley, by repeating a great part of Hales's experiments, discovered a number of fluids, which, though they have the appearance of air, yet differ from

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it in all their essential properties: and, in particular, from metallic calces he extracted a species much purer than atmospheric air.

M. Bayen, a chemist deservedly celebrated for the accuracy of his researches, examined the calces of mercury, and found that they are reducible without phlogiston, and that during the process they emit an aëri-form fluid in great abundance.

M. Lavoisier, soon after this, discovered, and proved by a number of fine experiments, that in the process of burning or calcination, a portion of the air always enters into combination with the body which is calcined or burnt. In consequence of this discovery, he formed a sect of chemists who agreed with him in doubting the existence of phlogiston, and ascribed to the fixation or the disengagement of air all those phenomena which Stahl had referred to the separation or the combination of phlogiston. It must be granted, that this doctrine has been more fully demonstrated than Stahl's; and that it agrees better with that accuracy and method which have of late been introduced into the study of natural philosophy. In this light did it appear to the late M. Bucquet, who in his two or three last courses of lectures seemed to give it the preference. The most prudent part on this occasion certainly was, to wait till it could be determined by a greater number of facts, whether all the phenomena of chemistry might be explained by the theory of gases, without our having recourse to phlogiston. M. Macquer, sensible that a considerable revolution must necessarily take place in the system of chemistry in consequence of these discoveries, but thinking it impossible to account for all the phenomena without admitting the presence of an inflammable principle, substituted

light in the room of phlogiston; as the existence of the latter had never been strictly demonstrated, while the influence of light on many chemical phenomena is a well known and undeniable fact.

Since the death of that celebrated chemist, the science has been enriched with a variety of discoveries, all tending to confirm the new theory. The multitude of facts which I have been collecting during a period of twelve years, and the number of the experiments of other chemists, which, on a repetition of them, I have found attended with the same results, have finally convinced me of the justness of that theory, and have led me to consider those naturalists who still continue to maintain, with more or less keenness, the existence of phlogiston, as either unskilled in the science, or incapable of accuracy in their experiments.

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C H A P. III.

Concerning the Chemical Affinities.

IN the first chapter it was observed, that the means used in performing chemical operations, which have been arranged under the two general heads of Analysis and Synthesis, are imitated from Nature, who employs them in her operations. To illustrate that truth, we shall here explain what is understood by the chemical affinities.

A person cannot even enter upon the study of nature, without taking notice of that wonderful mutual force by which all natural bodies are attracted towards each other. On this great and universal law, all those phenomena depend which the philosopher contemplates with curiosity, and which even the most ignorant of men cannot behold without admiration.

This force, by which indeed the order of the universe is maintained, actuates the most minute bodies as well as the most enormous masses of matter. But it acts by laws, either essentially different, or at least differently modified, according to the mass, consistency, and distances, of the bodies subject to its influence. Without examining its effects on the planetary bodies,

whose distances and motions it regulates *, let us consider in what manner it affects the different parts of the globe which we inhabit, that we may by this means discover its laws.

Natural philosophy teaches, that when two solid bodies of the same kind come into contact, they adhere together with a degree of force proportioned to the extent and smoothness of the surfaces in contact. Thus, two planes of glass, or two sections of a metal sphere, if pressed together, unite with a degree of tenacity which renders a considerable effort necessary to separate them. This force produces all the phenomena observed in chemistry. It becomes, therefore, an object of the highest importance to study all its laws, and inquire what variations it undergoes from diversity of circumstances.

The greater part of chemists have denominated this force *affinity* or *relation*; because it has been thought to depend on an analogy or conformity of principles in the bodies between which it subsists. Bergman has given it the name of *chemical attraction*: and though its phenomena are different from those of the planetary attraction first observed by Newton, yet, as both depend upon the same principle, we shall follow Bergman in the use of the name. Chemical attraction may take place between bodies of the same nature, or between bodies of different natures. Let us consider it under these two points of view.

* Neither experiments nor analogy, as far as we know, authorize chemists to confound their affinities with the general laws of gravitation. This notion makes us recall to mind the universal medicine &c.

§ I. Concerning the Attraction or Affinity that takes place between Bodies of the same Kind, or the Affinity of Aggregation.

WHEN two bodies of the same nature, for instance two globules of mercury, placed at a certain distance from each other, tend, by virtue of this force, to unite, and do actually enter into union, they form a sphere greater in bulk, but precisely the same in nature. In that event, therefore, this force affects only the physical, or obviously apparent qualities of bodies; it joins separate portions of similar matter; by confounding together several distinct masses, it forms a body of greater bulk, and unites a number of separate parts into one whole. It is denominated the *attraction or affinity of aggregation*, in order to distinguish it from that which takes place between bodies of different natures. It produces an aggregate in which the physical qualities of the bodies united undergo a new modification, without any sensible change being produced on their chemical qualities. The *aggregate* is nothing more than a coherent body, the parts of which are retained in union by the force of aggregation. It must be distinguished from the mass called an *heap*; for though an heap consists of parts all of a similar nature, yet those parts are disposed loosely, and without coherence. It is likewise to be distinguished from a *mixture*; which consists of a quantity of dissimilar particles blended together without adherence. This may be farther explained by a familiar example: Flowers of sulphur, or sulphur in powder, whose parts have no adhesion, and may be separated by the slightest effort,

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compose

compose an heap, the parts of which are not affected by the affinity of aggregation. This mixed with another heap, with one for instance consisting of nitre in powder, gives what is called *a mixture by confusion*. But if, by the help of fusion and cooling, you subject this heap to the power of aggregation, the molecules or integrant parts of the sulphur will then be drawn towards each other during its liquefaction, and will mix and unite in such a manner as to form, when cooled, an uniform mass or solid, which will be a true aggregate.

The force or affinity of aggregation exists in various degrees, which are measureable by the effort necessary to separate the integrant parts of any aggregate body. We shall distinguish aggregates into four kinds, under which all the bodies in nature may be arranged.

1. The first is the hard or solid aggregate, in which the integrant parts are united by a very considerable force, and cannot be separated without great exertion. This genus comprehends many species or degrees, from the hardness of the precious stones and of rock-crystal, to the yielding contexture of the softest wood. Its peculiar characteristic is to form a mass, the constituent parts of which cannot suffer any discernible motion without being divided.

2. Bodies whose constituent parts may be easily moved backwards and forwards, so as to change their relative situation, without being separated, belong to the soft aggregate. Less force is requisite to maintain the cohesion of a soft body than to preserve the consistency of a solid aggregate; and less reaction to destroy it.

3. The fluid aggregate. Its integrant parts are so slightly united, that the gentlest effort is sufficient not only

only to change their relative situation, but even to divide them into distinct globules.

4. Lastly, the aeriform aggregate, the tenuity of whose integrant particles renders them imperceptible, and in which the affinity of aggregation is the least possible. The air of the atmosphere affords an example of this.

These four kinds of aggregate are, properly speaking, but different degrees of the same force: but it is absolutely necessary to distinguish accurately between them; because they have an important influence on the operations and phenomena of chemistry, which is diversified according to their differences: yet it may be proved in the most satisfactory manner, that they are only so many different degrees of the same force; for many bodies are capable of assuming each of these four states successively. Water, in the form of ice, is a solid aggregate; its hardness is greater in proportion as its temperature is lower; when exposed to the temperature of 32° Fahrenheit, it assumes a kind of softness* before passing into a fluid state. Its existence in this last state is universally known: and philosophers have calculated what degree of expansive force is necessary to reduce it to vapour; in which state it becomes an aeriform aggregate. Metals, grease, concrete oils, wax, &c. may be in the same manner caused to pass through these several states of aggregation.

The more particularly any person is acquainted with the laws of chemical attraction, so much the more will he be convinced of the importance of distinguishing

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between

* A doubt expressed by the translator of the second edition, caused me to repeat this experiment; and I found that M. Fourcroy had by no means misrepresented the fact.

between these several kinds of aggregation, and estimating each of them aright. Accurate ideas concerning each of them are essentially necessary to enable us to compare this with the second species of chemical attraction, which will come next to be examined.

As these two kinds of affinity, though they appear to depend on the same cause or principle, yet in all the phenomena of chemistry seem to act in direct opposition to each other (for it may even be inferred from facts which shall be related, that they are in the inverse ratio of each other), it is absolutely necessary for the chemist to weaken or destroy the one, when he wishes to effect any operation by means of the other. Now, the attractive force of which we have been speaking, is almost always that which he has occasion to diminish; and it likewise admits of various modifications by the power of art.

All that is necessary to destroy or weaken the affinity of aggregation, is, to oppose to the cohesion of the aggregate an external force more than sufficient to counterbalance that which preserves the union of its component parts; and the external force applied must therefore be proportioned to the adhesion of the parts. This is the great law to be always observed in the preparatory operations; the sole purpose of which is to destroy the affinity of aggregation. Pulverization, grinding, rasping, filing, and cutting, are so many means for counteracting the cohesion of bodies and dividing their constituent parts. Heat and evaporation produce the same effects on fluids, and on those solids which are susceptible of dilatation or fusion. But these last mentioned operations being effected by heat, come properly under the second species of chemical attraction; as does also the solution of bodies by water.

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As art can apply a great variety of means to counteract, and even destroy the force of aggregation; so it likewise affords others to restore it, and cause it to act with all its former energy. All the manipulations which it employs for this purpose, consist in placing the bodies, whose force of aggregation is to be restored, in such a state of division and fluidity, that their particles may be at liberty to obey the power of attraction, by applying to each other those of their surfaces which are best adapted to unite; and they thus form a new aggregate, which, in regularity of figure and cohesive force, is generally equal, and sometimes superior, to natural aggregates of the same kind. We may take this opportunity to observe, that all aggregate bodies may be divided by their figure into two classes, Regular and Irregular. Every body in nature appears under the one or the other of these two forms; and art, which always emulates, and sometimes even rivals, nature, can produce at pleasure a regular or an irregular aggregate. All substances capable of passing through the several states of aggregation above enumerated, but more especially salts and metals, may be so managed during the process by which they are reduced from a fluid to a solid state, as to assume the form either of an irregular mass, or of a body with regular lines, angles, and surfaces, which is called a crystal. The first form is obtained by keeping the particles of the fluid body, whether its fluidity may have been occasioned by fire or water, very near each other; and causing the liquefaction to cease suddenly, so that they may come into contact all at once, and the affinity of aggregation may cause them to unite into one irregular mass. But, on the contrary, to produce crystallization, it is necessary to keep the parts of the body which you wish to bring into

into that state, at as great a distance as possible from one another, that they may remain for some time in a kind of equilibrium, before coming into union, and may present to each other such of their surfaces as are best adapted to unite. From this it appears, that crystallization is entirely owing to the affinity of aggregation; and if the phenomena of crystallization be observed with a proper degree of attention, they will afford an idea of the manner in which the affinity of aggregation acts. For this purpose it is mentioned here: it shall be more particularly explained under several future articles of this work.

§ II. *Concerning that Species of Chemical Attraction which unites Particles of different Natures; or the Affinity of Composition.*

WHEN two bodies differing in nature have a tendency to unite, they enter into combination by virtue of a power somewhat different from that which we have been considering; it has been denominated *the affinity of composition*; but may be with more propriety named *the attraction of composition*. This species of attraction or affinity is of still greater importance than the former, as it acts in all chemical operations, and none of these can be explained without it. The existence of this power has been always known; but it was not observed with the attention which it justly merits, till such time as it appeared to affect the practice no less than the theory of the science of which we are treating. A knowledge of this affinity is essentially necessary to direct the practitioner who pursues a
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train of experiments, as well as the philosopher who collects and compares facts. This is the compass by which both must steer; and it may be affirmed, that whoever is well acquainted with the laws of chemical attraction, is acquainted with the extent and sublimity of the science.

Convinced of this truth, we shall here make it our business, first, to exhibit faithfully all the facts which can serve to illustrate the nature of this affinity; and, next, to give an account of those hypotheses which have been formed to explain its cause.

Observation, the parent not only of chemistry but of all experimental science, has shown, that the attraction, or affinity of composition, presents certain invariable phenomena; which may be considered as laws established by nature, and which can escape the observation of none but such as are incapable of examining them with due attention. These laws, founded on a vast variety of well-established facts, may be reduced to eight; which are as follows,

I. *First Law of the Attraction of Composition.*

The attraction, or affinity of composition, cannot act but between bodies of different natures.

This first law is invariable, and admits of no exceptions. That two bodies may combine, and form a compound, it is indispensably necessary for them to be different in kind. Join two bodies of the same nature, and you form only an aggregate, of which the bulk and extent are enlarged, but its essential properties remain unaltered; and their union is occasioned and preserved
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by the affinity of aggregation, conformably to the explanation already given of the nature of that affinity. Thus, two pieces of wax, rosin, or sulphur, may be united by the action of heat; and this instance is sufficient to explain the difference between aggregation and composition.

This law holds so invariably, that the attraction of composition is never stronger than when the bodies between which it acts are, in nature, the most essentially different from one another. Thus acid salts and alkalis, though the properties of the one are directly opposite to those of the other, enter into the most intimate mutual combination, and form the most perfect compound. The same opposition subsists between the properties of alkalis and sulphur, of acid salts and oil, of acids and metals, of water and spirit of wine, &c.; all which substances have a strong tendency to mutual union.

It is the more necessary for us to gain an accurate knowledge of this great law of the affinity of composition, because a number of chemists, with Stahl at their head, have laboured to prove, that bodies never enter into combination, but in consequence of a certain relation, or resemblance between their properties: an opinion to which no person will agree who knows the full extent of this primary law. When reading the reasonings even of the most eminent chemists on this subject, we cannot avoid observing, that the relations which they labour to point out between those substances which have the strongest tendency to mutual union, appear always extremely remote; and that, by the same means, resemblances might be easily found out between bodies the most dissimilar. It is easy to see, however, that those ingenious men have proposed
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this theory, merely from a desire to simplify and illustrate the doctrine of chemical attractions: and those who are sensible of the difficulty of establishing systems in any of the departments of human knowledge, will always consider them as intitled to the gratitude of every friend of science. Their labours have not been without their use, as they have collected a number of facts, and pointed out their connection. But a regard to truth, which it becomes us to prefer to every other consideration, obliges us to confess our ignorance of the cause of this important phenomenon, instead of referring it to an analogy, the existence of which is inconsistent with those ideas of the properties of bodies which we derive from experiment.

II. *Second Law of the Attraction of Composition.*

The attraction of composition acts only between the minutest particles of bodies.

IN order to form a just idea of the nature of this law, it is necessary for us to distinguish chemical from physical subjects. These last are bodies whose external qualities, such as weight, bulk, surface, extent, and figure, are perceptible to our senses, and may be estimated by their effects upon them. Aggregates are the bodies whose qualities are observed and compared by the naturalist. Chemical subjects, again, are substances which have lost their aggregation; and which, of consequence, no longer present to the senses the physical properties of aggregates. They are minute particles, the extent of which cannot be measured, nor their bulk or form distinguished. It is not till after
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bodies have been reduced to this state of tenuity by the several preparatory operations above-mentioned, that they become subject to the affinity of composition; and the chemist cannot cause them to enter into combination, without presenting them to one another in a state of division. This force seems to actuate none but the minutest particles of bodies: and in this manner does the attraction of composition appear to differ from that which acts between large masses of matter. The difference is still more striking when we consider the constant opposition between the attraction of aggregation and that of composition. This opposition is so inviolable, that we may even venture to advance it as a chemical axiom, that the attraction of combination is in the inverse ratio of that of aggregation; these two forces being always in opposition, and forming a kind of counterpoise to each other. The attraction of aggregation always resists the combination of different bodies; where it acts with the greatest force, they have scarce any tendency to mutual union; and again, such substances as are least under the influence of the force of aggregation, have a strong tendency to combine with others. The various kinds of *gas*, or air, for instance, of all known substances are the least under the influence of the force of aggregation; and of them there are many whose tendency to combination is so strong, that they combine with the greatest facility with almost any natural body. Yet we shall afterwards see that this happens only when the heat which enters into the composition of elastic fluids is but slightly combined with a base; and that the aeriform state often occasions a contrary tendency; as for instance, in pure air.

III. *Third Law of the Attraction of Composition.*

The attraction of composition can unite more bodies than two.

THIS law of chemical attraction is one of those which have been established by the fewest observations; and we are still but very imperfectly acquainted with its extent. We are acquainted with a vast variety of those combinations which are produced by the union of two bodies; with a few which are formed by the union of three bodies; but we know of scarce any instances in which four different bodies have an equal tendency to enter into mutual combination, and remain in that state. Metals are the only bodies that are known to be capable of this last species of combination; and of which two, three, or four, may be effectually blended together. It is highly probable that there are in nature combinations made up of more than four bodies, of six or eight, for instance; but with such we are hitherto unacquainted. The reason why so little progress has been made in the study of this law, shall be explained when we come to treat of the eighth law of the affinity of composition. The number of the substances of which any composition consists is denoted by saying, the affinity of one, two, three, or four bodies, and so on. The rapid progress which chemistry has of late begun to make, the multiplicity of its researches, the variety of the objects to which they are directed, and the scrupulous accuracy of observation with which they are conducted, afford us reason to hope that those affinities which are named *complicated* will soon be better known.

IV. Fourth Law of the Affinity of Composition.

That the affinity of composition may take place between two bodies, at least one of the two must be in a fluid state.

THIS law has been long known to chemists, and has been long expressed in this axiom, *Corpora non agunt, nisi sint soluta*. Uniform and accurate observation has shown, that two solid substances can never enter into mutual combination. Even bodies which have the strongest tendency to unite, cannot be brought into union till either the one or the other of them be reduced to a fluid aggregate. Bodies enter into combination with more or less facility, according as they are more or less in a state of fluidity, and consequently possess more or less aggregative force: and therefore no two bodies enter into combination with such rapidity as any two of the saline aeriform fluids; for instance, the muriatic acid gas and the alkaline gas.

Though no two solid bodies can enter into combination with each other; yet in some instances dry substances, reduced into a fine powder, react upon each other with so much energy, as to unite and form a new compound. Thus I have discovered that caustic fixed alkali, when reduced by trituration, unites in a cold dry state with sulphur, antimony, and kermes, as I shall elsewhere more particularly relate: but in this instance, the reduction of the bodies into their most minute particles by pulverization, and the moisture of the atmosphere attracted by the salt, which soon deliquesces, have a considerable share in effecting the combination;

ination; and indeed bring this phenomenon under the law, which we are now engaged in examining.

But it is not always necessary that the bodies which you wish to combine be both fluids; it is enough that one of them be in that state. When they unite, a phenomenon takes place, to which chemists have given the name of *solution*. It consists in the attenuation, division, and entire destruction of the solid body in contact with the fluid. The cause of this phenomenon is, that the attraction of combination between two substances, one of which is a liquid, the other a solid, such as the sulphureous acid, and a bit of calcareous spar, is stronger than the aggregative force which preserves the particles of the solid in exclusive union with one another. Now since, by the third law, this species of attraction cannot act but on the most minute particles of bodies, the spar must necessarily lose its aggregation, and be reduced into very small particles, in order that it may combine with the *sulphuric* acid, and form *calcareous sulfate*. Formerly, chemists always distinguished between the body which effected and that which suffered the act of solution: the former was the fluid, the latter the solid. But modern chemists refuse to admit this distinction, as it supposes a force in the fluid superior to what exists in the solid aggregate. M. Gellert was the first who observed that the two bodies contribute equally to the act of solution; and that in the above instance, the vitriolic acid could not destroy the aggregation of the spar, had not the spar a tendency to unite with the sulphuric acid no less strong than that of the acid to combine with it. The same *solvent*, therefore, given at present to fluids, is not strictly chemical, as it conveys only the idea of a me-

chanical operation ; and it were better to lay it aside. But since it has been unluckily introduced, the students of chemistry must always remember, that when one body is said to dissolve another, no more is meant than that the former is in a fluid state, and that the fluid can never possess greater activity or energy than the solid ; but the solid may rather be considered as possessing these qualities in a superior degree, since its tendency to combination is so powerful as to overcome its aggregative force.

The false idea of solution which has prevailed till of late, arose no doubt from the mechanical theory by which some philosophical chemists have sought to explain this operation of nature. This theory, which appears in every page of Lemery's chemistry, consists in considering the solvent, an acid, for instance, as an assemblage of very acute points, and the body to be dissolved, as containing a vast number of pores, into which the points of the acid insert themselves, so as to disjoin the particles of the body, and reduce them to that state of division in which the aggregate disappears. To mention this opinion is, at present, all that is necessary to show its absurdity and inconsistency with those laws which accurate observation has established in the experimental sciences.

V. *Fifth Law of the Attraction of Composition.*

When two or more bodies are combined by this affinity, their temperature suffers a change at the instant of their union.

THIS phenomenon so invariably attends all the combinations effected by art, that we cannot help considering it as one of the laws of the attraction of composition. The temperature of bodies may be altered in two ways; new combinations sometimes produce cold, sometimes heat. The latter is oftener produced than the former: but as cold is certainly produced in several synthetic operations, we have thought proper to express this phenomenon by the general term, Change of temperature.

It may be objected, that in certain solutions or combinations which are slowly effected, no change of temperature is perceived: But we would desire those people who are disposed to offer such an objection, to immerse a good thermometer into those solutions, and they will not fail to be convinced that a change of temperature is produced. It appears from some valuable observations of M. Beaumé's, which shall be elsewhere more particularly mentioned, that this phenomenon is occasioned by the change of aggregation, which the bodies entering into combination undergo as they pass from a solid to a fluid state. But as that change is produced by the action of the affinity of composition, both the one and the other evidently depend on this principle.

Macquer has given it as his opinion, that the variations of the temperature of bodies entering into combination, are occasioned by the motion of their component particles: but though we should admit this as an happy account of the cause of the heat produced in new combinations, still the cold which takes place in some of them remains unexplained. Several modern chemists, particularly Scheele and Bergman, consider heat as a distinct body, acting a principal part in all chemical combinations; and assert, that change of temperature arises from the absorption or disengagement of this body. This theory affords a good explanation of the cause of that change of temperature which takes place when a new combination is produced.

VI. *Sixth Law of the Attraction of Composition.*

Two or more bodies united by the attraction of composition, form a substance, the properties of which are different from those which each of the bodies possessed before their union.

It is of importance to establish the existence of this law; because many celebrated chemists of the present age, have entertained opinions concerning the properties of compounds, which to us appear inconsistent with a great number of facts, and are directly contradictory to what we here offer as one of the principal phenomena of the affinity of composition.

Stahl and his followers, whose genius has, in other instances

instances, rendered so many important services to chemistry, have asserted, that compounds always partake of the properties of those bodies of which they are compounded, and possess a kind of middle nature between their principles. They have even carried this notion so far as to persuade themselves, that it is possible to determine the peculiar properties of any principles, by examining the compound formed by their union. Thus, Stahl pronounced salts to be a compound of earth and water, because he thought he could distinguish their properties to be intermediate between the properties of these two substances. As we are to examine this leading doctrine when we come to consider the general nature of salts, it would be improper to enlarge upon it here: We shall only observe, that those chemists who have adopted this opinion of Stahl's, have not been happier than he in the proofs which they have adduced to establish it; and that the intermediate properties which they have discovered in compound bodies, have always a very remote relation to those of their principles, as shall be clearly shown to be the case, even in the chief instances adduced by Stahl. I must even acknowledge, that what first induced M. Bucquet and myself to examine this theory with particular attention, and finally to adopt one directly opposite to it, was our observing with what difficulty, and how ineffectually, Stahl had laboured to establish it in his works. All that is necessary to prove the existence of this law, for which we reject the theory of Stahl, is, to produce some instances in which the properties of compounds are totally different from those of either of their principles. But the phenomena of all chemical combinations come under this descrip-

tion; not one but affords an instance in behalf of that truth which we wish to establish.

In order to show, *1st*, That bodies which enter into combination lose their original properties; *2^{dly}*, That they acquire new properties totally different from those that they before possessed; let us select some properties of which the variations may be easily distinguished. Taste is often a very eminent property in two distinct bodies, which when united are almost insipid in comparison with what they were in that respect before. *Sulfate of potash*, or vitriolated tartar, which is produced by the combination of two potent caustics, the sulphuric, or vitriolic acid, and pure *potash*, has only a bitter taste; which is by no means an intermediate between the caustic poignancies of those two salts. Again, two bodies with little or no taste, often acquire by combination a very strong taste; a few grains of the *oxygenated muriatic acid*, or a few grains of mercury given in a glass of water, can produce no bad effects on the animal economy; whereas if combined so as to form the *oxygenated mercurial muriate*, or corrosive sublimate, and administered in the same manner, they have a most pungent taste, and produce the most fatal effects on the human constitution.

Bodies entering into combination are no less liable to change of form. Two substances, neither of which is by itself susceptible of crystallization, often assume a regular form when combined together: thus the *muriatic acid gas*, and *ammoniac* or alkaline gas, when they enter into combination, form crystals of *ammoniacal muriate*. In other instances, the form suffers only a slight change of modification; as in the combination of certain neutral salts, in the union of
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fulphur with metals, and in allayed metals; which last have been observed by M. l'Abbé Mongez to afford crystals somewhat different from those of pure metals. *Lastly*, Bodies that are, in a simple state, highly susceptible of crystallization, lose that property when combined with other bodies. This happens to all metals when united with the *oxigenous* principle; and to some of them when combined with acids, &c*.

The consistency of bodies is also affected by their combination; the consistency of a compound being almost always different from that of either of the simple bodies of which it is composed. Thus, two fluids often produce a solid by their combination; for instance, the sulphuric acid united with a solution of potash. And again, a fluid often results from the combination of two solids; as from a combination of neutral salts with ice, and from the mixture of an amalgam of lead with an amalgam of bismuth. But the quality which suffers the most frequent alterations in the combination of bodies is colour. Sometimes it is lost: thus the coloured muriatic acid, combined with a metal, becomes white. But it oftener happens, that two bodies destitute of colour, assume when united either a fainter or stronger colour, as when iron or copper are dissolved almost in any of the acids, and when the calces of lead, mercury, or almost any other metal, are united with the *oxigenous* principle.

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* We cannot avoid making use of terms and denominations not yet explained. But the reader may have recourse to the table subjoined at the end of the last volume, and to the beginning of our account of the several articles to which such names belong, for an explanation of them. This inconvenience, though it may perplex the beginner, cannot be otherwise obviated.

Many bodies which, in a simple state, are strongly odoriferous, become inodorous when brought into combination; as for instance, the muriatic acid gas and the ammoniac or alkaline gas, which in a simple state have a strong suffocating smell, form in combination the ammoniacal muriate, a neutral salt that has scarce any smell. Again, from the union of two inodorous bodies, there often results a strong-smelling compound; sulphur and fixed alkali, each of which is in a simple state almost destitute of smell, form, when united, liver of sulphur, or *fulphure*, a substance which in a moist state is extremely fetid.

The fusibility of bodies is subject to the same changes. Two substances, not susceptible of fusion, or which cannot be reduced to that state without the greatest difficulty, when combined acquire the property of fusibility in an high degree. Combine sulphur with any of the metals, and you will have a striking instance of the truth of this assertion. A variety of other facts, besides those which have been here adduced, concur to establish this law in contradiction to the theory of Stahl.

VII. *Seventh Law of the Attraction of Composition.*

The attraction of composition is measurable by the difficulty of destroying the combination formed between two or more bodies.

CHEMISTS know how to separate bodies in union, however strong their mutual attraction or adherence; but

but the means which they employ for that purpose are more or less easy, more or less complicated. It has been uniformly observed, that in proportion as a compound is more or less perfect, its component parts are separated with more or less difficulty: And the degrees of the difficulty with which any two substances are separated, may be therefore considered as in direct proportion to the degrees of the attraction by which they mutually adhere; from the one we may form a just estimate of the other.

We consider it as particularly necessary to insist on this law, because beginners are apt to fall into mistakes in estimating the differences of the attraction which unites the principles of different combinations. From the rapidity with which some substances combine, we are ready to imagine that their mutual attraction must be very considerable. But long experience shows that this eagerness to enter into combination, instead of indicating a perfect composition, is rather a proof that the attraction between the bodies is extremely weak, and can produce but a very imperfect compound. In order, therefore, to determine accurately the degree of affinity with which bodies unite and remain in union, we must consider the ease or difficulty with which they are separated. This will be farther explained by an examination of the eighth and last law of this species of chemical attraction.

VIII.

VIII. Eighth Law of the Attraction of Composition.

Bodies have not all the same degree of chemical attraction with regard to one another; and the degrees of that force subsisting between different bodies may be determined by observation.

NATURAL bodies have not uniformly the same tendency to mutual combination. There are even some bodies which absolutely refuse to unite, or between which at least art cannot effect a direct combination; such as iron and mercury, water and oil, &c. though it is not true that these bodies have no mutual attraction. Others require long time and much pains to bring them into combination.

But the most important circumstance of this variety of chemical attraction is, that since various bodies are united with various degrees of force, we may acquire such an accurate knowledge of the particular degree of force which unites any two bodies, as to effect a separation between them at pleasure. Bergman has contrived the name *elective attractions*, to indicate that there is a kind of mutual choice between those bodies, which in order to combine with one another, separate themselves from those other substances with which they were before united, and entirely forsake their former state. This decomposition is even the grandest effect of the chemical art: by this the chemist is often able to perform what appears altogether miraculous to persons unacquainted with the principles on which he proceeds. To comprehend the nature of this decomposition,

sition, let us suppose two bodies to be united with a force equal to four; as for instance, an acid and an *oxide*, or metallic calx: Let us bring a third body, such as an alkali, which has an affinity with the acid equal to five or six, into contact with this compound; the consequence will be, that the alkali, whose tendency to combine with the acid is greater than that of the acid to remain in union with the metallic *oxide*, will desert the latter in order to combine with the former. This is precisely the result of such a mixture, the metallic *oxide* appears in a separate state, and a new combination is formed, consisting of the acid and the alkali. This decomposition is commonly known by the name of *precipitation*; because the substance separated generally sinks to the bottom of the fluid compound.

The substance that sinks to the bottom of the vessel in which this operation is performed, is named a *precipitate*. The substance by the addition of which the phenomenon is produced, is denominated the *precipitant*. There are four different kinds of precipitates. A *true precipitate* is formed, when the substance which sinks to the bottom is one of the principles of the compound decomposed by the addition of the new body. When sulfate of lime, which is a combination of lime and the sulphuric acid, is decomposed by means of potash, which substance has a greater affinity with the acid than with lime, the lime being separated falls to the bottom, and constitutes a true precipitate. A *false precipitate* is produced, when the new combination of the precipitant with one of the two simple bodies of the compound which it has decomposed, falls to the bottom on account of its insolubility, while the separate body remains in a state of solution. When *mercurial*

rial nitrate is decomposed by the muriatic acid, with which the oxide of that metal has a stronger affinity than it has with the *nitric acid*, the new combination of mercury with the muriatic acid sinks to the bottom of the mixture, forming a false precipitate, above which the nitric acid remains dissolved in water. This phenomenon depends entirely, as shall be elsewhere shown, on the different degrees of the solubility of the different substances.

We cannot avoid observing, in this second order of precipitates, an error of denomination which may tend to mislead beginners. For, if this name be given to the substance separated from the compound by the precipitant, it cannot with any propriety be applied to the new combination then formed. But though we should even confine the term *precipitate* to denote the substance separated by the precipitant, it might still occasion mistakes; as it happens in many cases that the insulated substance, instead of sinking, rises and is volatilized. Thus, when the combination of the muriatic acid with volatile ammoniac or alkali, known by the name of ammoniacal muriate, is decomposed by quicklime, with which the acid has a greater affinity than with volatile alkali, the alkali evaporates, and the mixture affords no appearance of any precipitate.

In order to produce these precipitates, it is necessary that the substances be in a liquid state: The process is then called precipitation effected in the humid way, to distinguish it from that which is accomplished by the action of fire, or in the dry way, either by means of fusion or distillation; which operations shall be hereafter particularly explained.

Modern chemists have likewise taken notice of two
other

other species of precipitate; the distinction between which is much more just and useful than that between the preceding. These are *pure precipitates* and *impure precipitates*. The first comprehend all bodies which, after their separation from those compounds into which they entered, exhibit all their original properties, without appearing to have suffered any alteration, in consequence either of existing in a compound state, or of being exposed to the act of decomposition. The precipitates of this species are very numerous, but the impure precipitates still more so.

In order that precipitates may be obtained very pure, it is requisite that they should have suffered no alteration by the action of the bodies with which they were combined before their precipitation; and that there subsist no affinity between them and the substance employed to precipitate them. For instance, when *alcohol*, or spirit of wine, is poured into a solution of sulphate of potash, the spirit of wine having a stronger affinity with the water than the water has with the salt, the latter is left in a separate state, and becomes a pure precipitate, because it has suffered no alteration from the water, and has not the most distant affinity with the alcohol. But when two bodies by combination have produced mutual alterations on each other, as happens in the combination of acids with metals, the third body, such as an alkaline salt, employed to effect a separation between them, will give the metal in a state very different from its original character, and will thus produce an impure precipitate. The same result takes place when the precipitant has any tendency to unite with the precipitate: thus, in the abovementioned instance of a metallic solution decomposed by an alkali,

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part of the alkali entering into combination with the metallic oxide renders it an impure precipitate. These two causes of the impurity of precipitates are almost always found to act together. We can sometimes distinguish at once whether a precipitate be pure or impure, by adding a much greater quantity of the precipitating body than is necessary to decompose the compound. This extraordinary quantity then enables the precipitant to combine with the precipitate, if there be any affinity between them, and dissolves it so entirely as to make it disappear. If a quantity of volatile alkali or ammoniac be poured upon a solution of copper with the nitric acid, the copper is precipitated in the form of light blue flakes. The colour of this precipitate, so very different from the natural brilliancy of copper, shows it at once to be an impure precipitate: If we add more ammoniac, this will still more plainly appear. The blue flakes are again dissolved by the salt, the fluid becomes gradually homogeneous and transparent, and assume a very fine deep blue colour; a sure proof of the combination of the oxide of copper with the alkaline salt.

For our present accurate knowledge of these impure precipitates, which occur much more frequently than the pure, we are indebted to the researches of M. Bayen concerning the decomposition of mercurial solutions with alkalis, and the state of mercury precipitated in those operations.

It is now easy to understand the theory of the decomposition of compounds of two bodies by means of a third brought into contact with them: they all depend upon simple elective attractions.

But beginners will find more difficulty in acquiring a distinct idea of that complicated phenomenon

which

which chemists have given the name of *double elective attraction*. It often happens that a compound of two bodies cannot be destroyed by a third or fourth body individually; while, if a compound of the two last be brought into contact with the first compound, both compounds are instantly decomposed. An example will make this better understood: Sulphate of potash, or a combination of the sulphuric acid with potash, cannot be decomposed by either quicklime or the cold nitric acid individually; but pour into a solution of the former neutral salt a proper quantity of the *calcareous nitrate*, formed by the union of the nitric acid with quicklime, the two combinations will be mutually decomposed; the nitric acid uniting with the potash to form common nitre, while the sulphuric acid uniting with the lime, forms sulphate of lime; which being less liable to solution than the nitre, is therefore precipitated. This affinity may possibly appear strange and unaccountable; but it may be explained in the following manner: The sulphuric acid cannot be separated from potashes, either by lime or by the nitric acid, because it has a stronger affinity with that alkaline substance than either of the two latter bodies has with it or with the alkali. But when you present to the sulphate of potash a compound of the nitric acid with lime, the nitric acid immediately exerts its tendency to combine with the potash, while the sulphuric acid is at the same time attracted by the lime; so that the decomposition of the sulphate of potash is begun by the action of the nitric acid, and completed by that of the lime. To explain this double affinity still more clearly, let us suppose the force of adhesion, which unites the sulphuric acid with potash, to be equal to eight; the nitric acid tending to unite with that alkaline substance

stance with a less degree of force, which we may estimate at seven, would be insufficient of itself to decompose the sulfate of potash; but the lime, by its tendency to combine with the sulphuric acid, aids it with a force which we may consider as equal to six; and these two forces together amount to thirteen; - which sum of forces is exerted against the force eight, to separate the sulphuric acid from the potash. This compound force will also be greater than that which maintains the union between the lime and the nitric acid.

There are therefore two kinds of attraction in double elective attractions, which must be carefully distinguished from each other: 1. The first is that by virtue of which the principles of each of the two compounds adhere to one another, which in the above instance retains the sulphuric acid in union with the potash, and causes the nitric acid to adhere to the lime. I shall follow Mr Kirwan in giving to this force the name of *quiescent attractions*; because its tendency is to preserve the two compounds in their first state. 2. The second is that by which the four principles of the two compounds reciprocally change their situations, and are combined in a different order: it is by virtue of this affinity, that in the above instance the potash combines with the nitric and the lime with the sulphuric acid. This second force I shall denominate *divellent attractions*; because it counteracts and destroys the first. From this useful distinction, it becomes easy to explain the cause of this double decomposition, by exhibiting in a table, as Bergman has done, the forces of the attractions by which it is produced. Place the two compounds which mutually decompose one another between two braces directly opposite, the acids

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acids standing in opposition to the bases on which they act; between these four bodies note down the particular degrees of the attractive force which they exert upon each other; add together the two horizontal numbers, expressing the quiescent attractions; add also the vertical numbers which are employed to mark the divergent attractions: if the sum of the latter exceed that of the former, a double decomposition and a double combination will be effected. The usefulness and accuracy of such a table may be shown at once by giving an example of it in the last mentioned compounds.

E X A M P L E.

Nitre, or nitrate of potash.

Sulfate of Potash.	Potash	7	Nitric Acid.	Calcareous Nitrate.
	8 quiescent	divell. attract. 6	attract. 4 = 12	
	Sulfuric Acid.	13	Lime.	
Sulfate of lime *.				

Chemists have but lately begun to take notice of these double elective attractions; and we are far from knowing them all. Those who are engaged in chemical

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* I have given ten similar examples of double decompositions which take place in the mixture of neutral salts, in two dissertations; which the reader may consult. See my *Memoirs and Observations on Chemistry*, Vol. I. 8vo, Paris, 1784, page 308 and 438. A.

researches, will frequently observe this kind of decomposition in circumstances where no such phenomenon was before suspected to take place. In the history of saline substances we will repeatedly have occasion to take notice of several of those double elective attractions which have been lately observed by Bergman, Scheele, &c. and by ourselves.

Before concluding our account of this tenth and last law of the attraction of composition, we cannot help taking notice of an ingenious method contrived by a French chemist, to exhibit at once all the more regular phenomena of chemical decomposition. Geoffroy the elder, observing the various relations which subsist between different bodies, and the precipitations produced in consequence of those relations, with more attention than had been applied to that object by former chemists, contrived, in the year 1718, to exhibit them in a table; in which he arranged those bodies whose affinities he had observed, in the order of their affinities. We only mention that fine contrivance in this place; but will have many future occasions in the course of this work of explaining it more particularly. Geoffroy gave that table only as a first attempt, to which he well knew much might be added. A number of chemists have adopted and enlarged his plan. Rouelle the elder made some corrections on his table, and added several columns to it. M. de Limbourg, a physician at Spa, in an excellent dissertation on the affinities, which, in conjunction with another by M. Sage of Geneva, gained the prize offered in 1758 by the academy of Rouen, has formed one still more extensive. M. Gellert, in his *Metallurgic Chemistry*, has likewise given a new table of affinities. But none has contributed more to the advancement of this part of the science

science than Bergman, professor of chemistry at Upsal; whose labours have been so beneficial to the science in general. That celebrated chemist has followed M. Baumé, in distinguishing the attractions which operate in the humid way, from those which effect combinations in the dry way. He has given two very extensive tables, in which he exhibits the elective attractions of a vast number of natural bodies. To the same philosopher we are indebted for a very ingenious table, in which he has found means, by a peculiar disposition of the chemical characters, to express the phenomena of double elective attraction: Of this we gave an example above.

After giving this view of the leading phenomena of chemical attraction, and unfolding the laws by which that force appears to be regulated, we must observe, that in some cases those laws seem liable to certain variations. We need not here mention all the facts on which this assertion is founded, as we shall be careful to take notice of them wherever they occur; only we may observe, that those seeming anomalies of chemical attraction arise from the influence of particular circumstances; such as the quantity of the substances, the temperature of the atmosphere, motion or rest, solution by water or fire, that is, in the humid or in the moist way, the state of aggregation proper to each body, &c. Bergman has considered all these circumstances with peculiar care; and has shown how far they may be expected to vary the laws of attraction. From the various facts which he has collected relative to this subject, he concludes, that these variations can be regarded only as exceptions, by no means sufficient to weaken the evidence on which the doctrine of chemical attraction is founded.

We are led to consider two other species of affinity that have been admitted by some authors, in the same light, the affinity of *intermediates* and the *reciprocal* affinity. By the first, they understand that by which bodies, which have no natural tendency to mutual union, are capable of being united after one of them has been combined with a third body, which serves as an intermediate between them: Oil, for instance, does not combine with water; but a combination of oil with a salt constitutes a soap, which is soluble in water, the salt acting as an intermediate. But it is not the salt which renders the soap soluble, for its properties are entirely lost in the soap; the solubility of this compound in water is owing to the new properties it has acquired. This phenomenon falls evidently under the eighth law of chemical attraction; by which it is established, that compounds acquire new properties totally different from those of their component principles.

The *reciprocal affinity* takes place when a compound consisting of two bodies is decomposed by a third, and the separated principle again decomposes the new combination; so that the principles seem to act reciprocally. The sulphuric acid has a greater affinity than the nitric acid with potash, and accordingly decomposes a combination of these two principles; but the nitric acid, when left in a separate state, has power to divide the sulphuric acid from the alkali; for by heating sulphate of potash with the nitric acid, nitre is again obtained. This kind of affinity, admitted by M. Baumé, is occasioned by two circumstances, whose influence disturbs the general laws of chemical affinity. The common nitric acid must be warmed before it can decompose sulphate of potash; and the nitre obtained by this process is again decomposed by the sulphuric acid, as soon as the mixture returns to a cold state. The fuming

or *nitrous acid*, decomposes sulfate of potash cold; fuming spirit of salt or muriatic acid effects the same decomposition, according to M. Cornette: but Bergman has very properly observed, that the odorating and fuming acids, which he calls *phlogisticated*, have affinities different from those which belong to them in their simple state. Besides, in these cases but a very trifling part of the salt is decomposed.

In all these instances, the order of elective attractions is changed and modified by particular circumstances. The rest of the facts on which Mr Baumé establishes the existence of the reciprocal affinity, such as the decomposition of ammoniacal muriate by chalk, and of calcareous muriate by *concrete volatile alkali*, come properly under the double affinities; as shall be shown when we treat of those salts.

All that now remains to be said on chemical attraction is, to give some account of the different opinions which have been advanced by philosophers concerning the cause of this force.

The first who attempted to form a theory on this subject, thought that it must arise either from the elementary particles of bodies being all of the same form, or from the physical configuration of the parts, or lastly, from some occult relations of their intimate composition. These notions proceeded naturally from the mechanical explanations which were applied to all the phenomena of nature, in the infancy of the science of natural philosophy.

Most of the modern chemists who have attempted to explain the cause of chemical attraction, have observed a remarkable analogy between this force and the general attraction discovered by Newton. Considering nature as simple and uniform, they have been led to conclude, that the power possessed by bodies of enter-

ing into mutual union, must depend on the same general laws with that by which all bodies are attracted towards each other. They have compared the minute bodies on which the force of affinity acts, with those enormous masses which compose the system of the universe; and have ventured to affirm, that it is the force of gravitation which causes the former to approach each other, and enter into combination. Several persons, adopting this opinion, but modifying it in a particular manner, have concluded, that chemical attraction was in the ratio of the gravity of bodies, and those bodies which were of the greatest specific gravity possessed always the strongest affinities. This hypothesis is sometimes indeed justified by facts, and agrees with the affinities of many of the acids; but is contradicted by the phenomena of a vast number of decompositions, particularly of all those in which metallic substances are concerned. Some chemists have been even so strongly persuaded of the existence of an analogy between the attraction of large bodies and chemical attraction, as to imagine it possible to measure and calculate the former in consequence of our knowledge of the latter. M. de Morveau, whose opinions are likely to have considerable weight with other chemists, has made a number of experiments with a view to prove the truth of the above assertion. Applying to a surface of mercury metal plates of the same diameter, suspended from the arm of a balance, the other arm of which carried a dish, he next put weights into the dish sufficient to raise the plate of metal over the mercury; and he actually found, by making comparative trials of different metals, that these adhered to the mercury with different degrees of force, proportioned to the affinities known to subsist

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between them and that substance. [Gold adhered with the greatest force to the mercury, a greater weight being necessary to raise it than to raise any of the other metals: Cobalt, again, which is known to have no affinity with mercury, seemed to have no adhesion with that surface, and was elevated above it with the greatest ease. But we must use the freedom to observe, that from several circumstances, such experiments cannot but be in some degree fallacious: the inferior surface of the smooth plates of metal applied to the mercury, cannot but combine with that substance; and the amalgam formed by that event being more or less, according to the ease or difficulty with which the metal unites with the mercury, this combination increases the weight of the plate, and renders a greater force requisite to raise it above the mercury. A plate of metal adhering to a surface of mercury, cannot be raised above it without dividing the mercury into two layers; so that the force necessary to raise this plate is employed rather in overcoming the mutual adherence of the particles of the mercury, than in dividing the mercury from the metal.

It must be acknowledged then, that if chemical attraction be the same with general attraction; yet the difference of the laws by which these two forces are regulated, proves the former to be a particular modification of the latter. This truth becomes evident from a comparison of those laws of the Newtonian attraction with which we are acquainted, with the general facts relative to chemical attraction which have of late been discovered: The former acts only upon large bodies, and in the direct ratio of their masses; the latter affects only minute bodies, and

has absolutely no influence on such as are of any considerable bulk. Attraction acts between bodies placed at immense distances from each other: affinity never acts but between bodies in mutual contact. In describing the laws of chemical attraction, we have laid before our readers the facts on one side of this comparison; and we are induced to conclude, that the phenomena which those two great laws present, are still so strikingly different, as to render it highly proper for philosophers to distinguish between them.

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C H A P. IV.

Concerning the Principles of Bodies.

IT has been the opinion of philosophers in all ages, that notwithstanding the vast diversity of the bodies of nature, they are all composed of a few primary simple substances; and to these they have given the name of *Principles*. The analyses of chemistry, which afford the strongest facts in proof of this doctrine, having enabled chemists to form pretty accurate notions concerning the nature and differences of those principles; they have admitted several kinds of them. But it must be remarked, that they have taken the word *principles* in an acceptation different from that in which it was used by the philosophers of antiquity. Aristotle and Plato applied the name *principles* to a class of substances, which being of such subtlety as to escape the observation of the senses, constituted, as they thought, by their union, those bodies of a less simple nature, and perceptible to the senses, which still continue to be known by the name of *elements*. These are the same substances which have been by other philosophers denominated *atoms*, or *monads*. But chemists, not presuming to extend their speculations to such sublime
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and subtle objects, comprehend under the general name of *principles*, all those substances, whether simple or compound, which they obtain by the analysis of bodies. But as the principles of bodies, when considered under this point of view, must be extremely various, they have divided them into *proximate* and *remote*. The first are obtained by a first analysis, and are capable of being resolved into other principles; thus, by decomposing a vegetable substance, we obtain oils, mucilages, salts, and coloured particles; all which are proximate principles of the vegetable substance, and each of them may by a new process be decomposed into other principles. By remote principles, they understand those substances which, being simpler than the proximate, enter into their composition. Thus, mucilage, one of the proximate principles of vegetables, affords by a new process, oil, water, earth, &c. and these are the remote principles of the vegetable. These two kinds of principles have been also distinguished by other names; such as *principiated*, applied to the proximate principles; and *principiant*, to the remote. These epithets distinguish the former as arising from the combination of more simple principles; and the latter, as serving by their union to constitute bodies, which though of a less simple nature, may yet become the principles of new compounds. Some chemists, to render these distinctions more just and accurate, admit more than two kinds of principles: They call those principles which appear so simple as to be incapable of farther decomposition, *primary*, or principles of the first order: *secondary* principles are formed by the combination of the *primary*; the combination of the *secondary* constitutes *ternary* prin-

principles; and these united in a new composition, afford *quaternary* principles, &c.

Philosophers have not uniformly agreed with regard to the number of the elements. The followers of Thales the Milesian, who for his superior knowledge was ranked among the seven wise men of Greece, and, according to Cicero, was the first among the Greeks who cultivated the science of physics, considered water as the great principle of all material bodies. Anaximenes, ascribing this character to air, ranked it, on that account, among the number of the gods. Others conferred this important function on fire; while some, among whom was Anaximander, the scholar of Thales and master of Anaximenes, believed earth to be the principle of all things. Each of them supported his opinion by reasonings more or less plausible: But as the experimental sciences of natural philosophy and chemistry were then unknown, we can regard these notions in no other light than as bold conjectures, which unfortunately happen to be totally destitute of foundation. About three centuries after these philosophers, Empedocles, a physician of Agrigentum, imagined that the four substances, each of which had been in its turn held to be the principle of all things, were of equal simplicity; and therefore combined those various opinions into one system, admitting four elements, fire, water, earth, and air. His opinion was adopted by Aristotle and Zeno in the following century. What induced those philosophers to consider fire, water, earth, and air, as elements, seems to have been rather the bulk, quantity, and apparently uniform properties of these substances, than any accurate notions concerning their essential composition. Fire seems diffused through all nature, and its effects are always the same: Our globe

globe is surrounded with a mass of air, of which the quantity and essential properties seem to remain unvaried: An enormous mass of water, whose depths are often unfathomable, covers more than half the globe: Lastly, this globe itself, the bulk of which is more than equal to that of all the beings who inhabit it taken together, seems to be formed of a solid matter little subject to change, and of such a nature as renders it a proper base to fix the other elements. It seems to have been on account of the bulk and unvarying properties of those bodies, that the first philosophers were induced to consider them as the primary materials of which all natural bodies were composed.

The peripatetic doctrine of the schools supported the Aristotelian distinction of the elements till the sixteenth century. The sect of chemists who then began to prevail, introduced a new distinction of the elements. Paracelsus, who was rather an artist than a philosopher, hastily inferred from the results of his operations, that there were five principles: namely, spirit, or mercury; phlegm, or water; salt; sulphur, or oil; and earth. By spirit, or mercury, he understood all volatile odorate bodies; but these properties are far from being peculiar to simple bodies. Water, or phlegm, comprehended all aqueous, insipid, products; but these properties are no surer indications of simplicity than the former. The word sulphur, or oil, he applied to all inflammable liquid substances, and of consequence to a great number of compounds, such as the unctuous and essential oils, &c. By salt, he meant all bodies possessing the three properties of dryness, taste, and solubility; which properties likewise belong to many compounds. Lastly, Paracelsus applied the word earth to all those fixed, dry, and insipid, residues which are
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obtained in most operations, and are now known to be very different in their natures.

Beccher, who has treated of the science of chemistry in a very philosophical manner, being aware of the objections to which this system of Paracelsus was liable, and convinced of its inaccuracy, attempted to distinguish the elementary principles of bodies in a different manner. He first assumed two principles very different from one another; moisture and dryness, earth and water. The latter of these he divided into three species; namely, vitrifiable, inflammable, and mercurial earth. His vitrifiable earth was that which, taken alone, was not susceptible of any alteration, but possessed the property of forming fine glass when mixed with a certain saline substance: he likewise ascribed to it the quality of rendering those bodies into the composition of which it entered solid, and almost incapable of alteration. Inflammable earth was that which rendered all the bodies into which it entered capable of combustion: Beccher considered it as being likewise the cause of odour, colour, and volatility. Mercurial earth he considered as existing in mercury, arsenic, the muriatic acid, &c.; and the distinguishing characteristic which he assigned it, was to communicate an high degree of both gravity and volatility to those bodies of which it constituted part, though these two qualities seem directly opposite and inconsistent. Stahl adopted and illustrated the doctrine of Beccher. He considered inflammable earth as fire existing in a fixed state, and gave it the name of *phlogiston*. He found himself unable to demonstrate the existence of mercurial earth; and we have hitherto obtained no certain knowledge concerning that principle. Stahl paid great attention to combinations of earth and water,

water, and still more to phlogiston, but has said scarce any thing of those which contain air; which Hales, nearly about the same time, discovered to act an important part in chemical phenomena.

From the days of Beccher and Stahl to the present time, chemists have made no change on the doctrine of the elements established by the philosophers of antiquity. They have followed Empedocles in acknowledging four principles, each of which they have considered as existing in two different states. 1. As free and insulated; and in this state have the atmosphere, large masses of water, fire in general, and the globe viewed as one whole been considered: 2. As combined; and then the air, water, and earth obtained by the last analytical operations that can be performed on bodies, are the subjects of inquiry.

Such nearly were the opinions concerning the principles and elements of things that prevailed from the time of Beccher and Stahl, till the noble discoveries of Priestley and Lavoisier, concerning fire, air, and combustion, exploded these, to make way for others better founded. In fact, if immutability of properties, unity and simplicity, are the genuine characteristics of elements, and if that simplicity of character belongs only to such bodies as we cannot reduce by decomposition, it is to be remarked, 1st, That of the four elements there are two, air and water, which art has at length found means to decompose and separate into several principles. 2^{dly}, That elementary earth is merely the creature of fancy; as there are a variety of earthy substances all equally simple and incapable of decomposition, as shall be shown in the last chapter of this first part: 3^{dly}, That there are many natural bodies, such

as sulphur, is able to present itself in substance.

From the time which follows, in the next chapter, appears, that the natural bodies, and of the imperfect substances with their bulk, and their motions, are, and that, are acquainted with the ascribe to them, have been able to agree with who consider substances, but infinitely.

What we have for elements, not hindered air, as for natural bodies.

Let us terms which distinguish more or less.

as sulphur and the metals, which no art has yet been able to decompose, and which must therefore, in the present state of our knowledge, be considered as simple substances.

From these general considerations, arising from facts which shall be more particularly related in the following chapters, and through the series of the work, it appears, that the true principles, or primary elements of natural bodies, escape the observation both of our senses and of those instruments which we employ to aid the imperfection of our senses: that many of those substances which have been called elements on account of their bulk, their influence on the phenomena of nature, and their being found to exist in many of its productions, are far from being simple and unchangeable: and that, in truth, none of the bodies with which we are acquainted is a simple substance, though we may ascribe that character to such as we have not hitherto been able to decompose. And these assertions entirely agree with the opinions of some ancient philosophers, who considered not the elements as the simplest of substances, but believed them to be formed of principles infinitely more subtle and immutable.

What we advance concerning those substances which have for so many ages enjoyed the exclusive title of elements, but are now divested of that prerogative, does not hinder us from considering fire, water, earth, and air, as forming the component principles of most natural bodies.

Let us dismiss this subject with an account of the terms which have been employed by some persons to distinguish bodies, according as their composition is more or less complicated.

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The combination of two elements forms a body that is called a *mixt*; the union of several mixts constitutes a *compound*; two compounds make a *surcompound*; the combination of surcompounds gives a *decompound*; two or more of these united make a *surdecompound*. It would be pretty difficult to give instances of these several kinds of compositions; we could indeed go no farther than to the surcompound. These distinctions are, therefore, merely fanciful, and can be of no real use in science. Macquer, to whom chemistry is much indebted for the present perspicuity of its doctrines, proposes to explode this barbarous and inaccurate nomenclature, and to adopt in its room, First, Second, Third, and Fourth Order. We might even pursue the same thought, so far as to adopt these names to distinguish principles according to the order of the analysis by which we obtain them.

C H A P.

THOUGH elements are really understood, not confused with all others, we are wiser in proceeding to properties is our account because the divisions of matter are particular departments through a process. None of these are or simple philosophers, who followed the substance penetratingly and incidentally and fluidity and

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Of Fire.

THOUGH we cannot agree to receive the word *element* in the same sense in which it was generally understood till the present time; though we cannot consider those four bodies as the first principles of all others, and the simplest productions of nature; yet we are willing to inquire into their nature before proceeding to others; because a knowledge of their properties is necessary to enable the reader to understand our account of the properties of other substances, and because they cannot be arranged under any of the divisions of natural history, being confined to no particular departments in nature, but extending equally through all.

None of the four elements displays greater activity or simplicity than *fire*. The more ancient philosophers, who in this particular have been uniformly followed by their successors, gave this name to a substance which they supposed to be fluid, active, penetrating, consisting of particles actuated by a lively and incessant motion, and the first principle of all fluidity and motion. Whoever considers this subject,

must readily perceive, that it was merely by conjecture they ascribed these properties to a particular elementary body : for though the existence of the other three elements has always been undeniably established, yet the existence of this has never been demonstrated. There is reason to think, that in all languages, and among all nations, the first use of this word was to denote the impression which hot bodies make upon the skin ; and that it is significant of the light which issues from bodies in combustion, as well as synonymous with the word *heat*. Many have considered it in this view, admitting the existence of fire only where heat is felt or combustion carried on. Chancellor Bacon was among the first that began to doubt the existence of fire as a particular fluid ; and observed, that natural philosophers, in defining it, had always mistaken a property for a substance. Boerhaave, whose *Treatise on Fire* will be ever regarded as a masterpiece, was sensible of this difficulty ; and in order to discover the properties of this pretended element, examined what effects it produces on those bodies in which it is believed to exist ; so, like former philosophers, he has rather given the history of hot, luminous, rarefied, and burning bodies, than of fire. This difficulty must even continue to perplex the philosopher. The properties of fire cannot but be intimately connected with those of the bodies on which it acts ; we can form no idea of it as existing in a separate state. Notwithstanding the present advanced state of chemistry, the existence of this substance is still undetermined. Philosophers continue to believe in its existence, but are able to give a satisfactory explanation only of its effects. These difficulties have induced several chemists, among whom was the celebrated Macquer, to consider fire as being

nothing

nothing more than light, and heat as a certain modification of bodies, produced by the motion and collision of their component particles. But this opinion no longer prevails among those who cultivate chemistry. In order to enter into the several theories which have of late been advanced concerning fire, we must consider it in a more particular manner. To acquire an accurate knowledge of this matter, and to comprehend that immense series of facts which at present constitute the body of the science of chemistry; we must make a methodical division of our subject, examine and discuss with pains its several parts and subdivisions, and consider in successive order, as so many distinct effects of fire, light, heat, rarefaction, the changes produced on bodies by heat, and the particular qualities ascribed to fire in a state of combination, when it obtains the name of Phlogiston, &c.

§ I. *Of Light.*

THE existence of light is not doubtful, like that of fire: both its existence and its properties are at present well known. This body, which is thought to issue from the sun and the fixed stars, is the principle which enables the organs of sight to inform us of the presence of other bodies. Without it we should be involved in perpetual darkness, and our eyes would be entirely useless. Being reflected in right lines from the surfaces of those bodies on which it falls, it strikes the eyes in such a manner as to paint on the retina the images of those objects from which it is reflected.

Means have been found to collect its rays in a darkened chamber, in such a manner as to render their properties subject to examination, by exhibiting them distinct from the bodies which they illuminate.

The motion of light is so rapid, that it passes through the space of eighty thousand leagues * in a second of time, according to the most eminent astronomers. It moves in a rectilinear direction, and consists of rays, which, after issuing from the stars, separate and diverge in obedience to the impulse originally communicated to them. Such is their elasticity, that when they fall on a surface capable of reflecting them, the angle of their reflection is nearly equal to that of their incidence; as is seen in the study of catoptrics. When light passes near any body, it is more or less inflected towards that body; which inflection, by evincing its gravitation, shows it to be a distinct substance.

However great its subtlety and velocity, yet it does not move invariably in a right line. Such bodies as meet and obstruct its passage, cause it to deviate from its original direction. When passing obliquely out of a rare into a dense medium, it is refracted like any other solid body; but Newton † discovered its refrangibility to be directly contrary to that of other bodies. Other bodies recede from the perpendicular line whenever they pass into a denser medium; but light on such an occasion, approaches nearer to the perpendicular. To explain the laws of the refraction of light is the province of dioptrics.

When light reaches the surface of the earth, it dis-

* Twenty-five of which make a degree; equal to 167,000 geog. miles.

† We owe the first accurate account of these phenomena to Descartes.

covers to animals the presence of material bodies, and enables them to distinguish them into opaque, transparent, and coloured. Its presence is so necessary to render these properties perceptible, that in darkness bodies become totally undistinguishable. Difference of opacity, transparency, and colour in bodies, depends, therefore, on the manner in which they are affected by light, or in which they affect that substance. A body is transparent when the rays of light pass easily through it; which depends no doubt on the form of its pores. As many transparent substances have great hardness and specific gravity, the particles of light which penetrate through them must therefore be extremely subtle. As the particles of light pass through those substances, they are refracted in the ratio of their density, if they be stones, salts, or vitreous substances: but transparent bodies of the combustible class reflect the particles of light in a different ratio. Thus, yellow amber has a much greater refringent power than a saline crystal of equal density.

By examining the various refractions and reflections of light, the great Newton was at length able to decompose, or rather to dissect, this body, so far as to discover that the rays which compose a beam of light were each of a peculiar colour. Before him mens notions of the cause of colours were very obscure and indistinct. The refraction and reflection of each ray of light are determined by particular laws; and therefore when a stream of light is directed so as to fall on the angle of a triangular glass prism, and the prism turned round on its axis, the rays which compose the stream of light being refracted according to different laws, are separated in passing through the glass, and if received on a plane white surface, form a long spectrum,

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consisting

consisting of the seven following colours ; red, orange, yellow, green, blue, purple, and violet.

The surfaces of opaque variegated bodies produce the same effects as the prism on light. Such seems to be the cause of that diversity of colours which constitutes so considerable a part of the beauties of nature. When all the rays which fall upon any opaque body are reflected, without suffering any absorption or separation by that surface, they strike our eyes with all their lustre, and the colour produced is a white : But again, if the same rays fall on a surface by which they are all absorbed, the eye then beholds a deep shade ; which being a direct contrast to the former, constitutes black, or rather absolute negation of colour. In short, as every beam of light consists of seven different coloured rays, of various degrees of refrangibility, what diversifies the colours of natural bodies is the various disposition of the particles of their surfaces ; some of which reflect one ray, absorbing all the rest, others another, and so on. Colour depends, therefore, on the nature of the surfaces of bodies, and transparency on the form of their pores ; and both are occasioned by the modifications produced on light, either by the superficies or the interior parts of the bodies on which it falls. A blue or red colour is produced by the decomposition of a beam of light, and the absorption of all its rays, excepting the blue or the red.

These are the chief properties of light, when considered in a free state, or as it issues from the sun and the fixed stars. But are we to examine it only in this free and insulated state ? Is not this body, as well as all the rest with which we are acquainted, subject to the laws of chemical attraction ? The phenomena of light are not confined to the modifications which

suffers

suffers from the surfaces of bodies. Substances exposed to its influence, by being plunged in its streams, often suffer an alteration and entire change of nature, without any other known cause; and it is reasonable to think that such changes are produced by the operation of light, which is enabled to effect them by being capable of chemical attraction. Art, indeed, has not yet been able to determine whether these alterations be occasioned by the decomposition of light, or by that of the bodies in contact with it, or by the mutual decomposition of both; which last is highly probable: but they are too numerous and too striking to be passed over unnoticed. We shall here mention only a few of the most remarkable; because our attention will be more particularly turned towards this object in the history of natural bodies.

Naturalists have long observed the influence of light on vegetation. Those engaged in the cultivation of plants first observed that such as grow in the shade are of a paler colour. This phenomenon has received the name of *ætiolation*; and the plants on which it takes place are said to be *ætiolated*. Herbs growing under stones are white, soft, aqueous, and insipid. Gardeners take advantage of this circumstance to supply our tables with white and tender herbs and pulse; for they bind their leaves so closely together, that the exterior defend the interior from the contact of the light. The colour of herbs is pale or deep in proportion as they are less or more exposed to the rays of the sun; and in consequence of this, the nations of the east obtain from the wood, bark, or roots of trees, many of the most valuable colouring stuffs, both for permanency and lustre, which all the ingenuity of European dyers has never been able to imitate.

Colour is not the only property that vegetables derive from the influence of light. From the same source they acquire taste, smell, and combustibility. Thus light contributes to the ripening of fruits and seeds; and under the torrid climate of America, vegetables in general are highly odorous, sapid, and resinous, &c. Lastly, light exerts so powerful an energy on the organization of vegetables, that when the rays of the sun fall upon them, their leaves pour from their superior pores copious streams of vital air; but when hid from the influence of that planet, they exhale a deleterious mephitic, or rather a real acid, of the same nature with that which is extracted from chalk. This important discovery was first made by Dr Priestley. M. Ingenhousze has prosecuted it much farther; and from the experiments and observations of both, it appears how powerful the influence of light is on vegetation. In a great number of chemical operations, light is found to act with the same energy as in these more general instances. There is not one substance in nature, that, if put into a close glass vessel, and exposed to the rays of the sun, will not suffer some alteration from their influence. These alterations are most remarkable in mineral acids, oxides or metallic calces, vegetable powders, and volatile animal oils. Not a single metallic oxide, though more especially that of mercury, but suffers a change of colour, assuming generally a deeper shade from being exposed to the rays of the sun. Painters' colours which are kept by merchants in glass bottles, afford a good instance of this. Mineral acids exposed to the sun become fuming, higher coloured, and more volatile; metallic salts become black; animal oils assume a brown, dusky colour. All of these changes merit the most careful attention of chemists.

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they afford vast scope to research, and have not hitherto been observed with sufficient care. Scheele was the first who described any of them. M. Berthollet has also turned his views to this object; and we shall afterwards see that he has determined accurately what passes in many of these alterations.

§ II. Of Heat.

TO examine the properties of heat is a much more difficult task than to examine those of light. Bodies when heated acquire no additional gravity; which might serve to prove that heat is a distinct substance. Bacon, and many other great men, have thought heat to be only a certain modification of which bodies are susceptible. It is certain that natural philosophers, as well as other men, have always considered its presence as a sure indication of the presence of fire; have sometimes confounded it with that element; and sometimes considered heat as one of the distinguishing properties of fire.

Its leading properties are, to penetrate through all bodies; to diffuse itself equally, and to tend to an equilibrium; to dilate all substances into which it insinuates itself, causing them to pass from a solid to a fluid state, and from that to assume the form of elastic fluids.

Heat is usually communicated to bodies in one or another of these three ways; by contact, by motion, or by combination. Every person must have observed, that when two fluids different in temperature, the one sensibly

senfibly warm, and the other fenfibly cold, are mingled together, the former lofes part of its heat, which is communicated to the fecond, fo that the temperature of both become the fame. It is equally well known, that when two folids, one warm the other cold, approach each other, the latter robs the former of part of its heat, and the temperatures become equal. As to the calling forth of heat by motion; the friction of any two folid fubftances, fuch as two hard ftones, two pieces of wood, ivory, or metal, produces a heat which often riles to inflammation. The production of heat by combination is no lefs undeniable. The union of concentrated acids with water, quicklime, pure alkalis, or metals, is productive of a ftrong heat: the combination of certain fluids, fuch as oil and fpirit of nitre, is even fo powerful this way as to caufe inflammation.

The laws of the communication of heat were confidered as analogous to thofe of motion, till the labours of Meffrs Wilcke of Stockholm, Irvine of Glasgow, Crawford and Kirwan of London, Lavoifier and De la Place of Paris*, gave us new and more accurate ideas on the fubject. The refearches of thefe philofophers have fhowed, that nothing was lefs known, or involved in greater difficulties, than the progrefs and communication of heat among bodies unequally heated. Their experiments, though highly ingenious, are not yet fufficiently numerous. They themfelves do not presume to confider their obfervations as of fufficient weight to form an elementary part in the fcience of chemiftry: But it is highly probable that thefe will lead to the

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* Dr Black of Edinburgh is certainly the author of the modern doctrine of Heat.

establishment of a general theory, which may be applied to all the phenomena of chemistry ; in every one of which heat acts a part, by either its absorption or disengagement.

Even the nicest and most accurate observations have been hitherto insufficient to afford us any determinate ideas of the nature of heat ; and both chemists and natural philosophers are still divided in their opinions on that subject. Part follow Bacon of Verulam, in considering heat to be nothing more than a modification of which all natural bodies are susceptible ; which has no separate existence, but consists in the oscillation of the minute particles of bodies. This was Macquer's opinion. The philosophers who maintain it, support it on the following facts. Heat accompanies all the phenomena of motion, and appears subject to the same laws : It is increased with the increase of motion, and diminished by its diminution. Excepting its communication or passage from one body into another, in which it follows laws different from those of motion ; in all other respects there is a striking analogy between the two ; and when this cause acts with less force, or entirely ceases to act, heat is instantly diminished, and soon totally lost. To explain this hypothesis, the philosophers by whom it is maintained observe, that even bodies of the greatest density are full of small cavities or pores, the sum of which if they were taken together would perhaps occupy a larger space than the solid matter of the body that contains them. These void spaces afford room for the particles to move one against another in a continual oscillation. The oscillations are not observed, because both the particles and pores are so subtle and minute as to elude our senses. Lastly, The philosophers who regard heat as an internal motion,

tion, urge, that no experiment has hitherto demonstrated its existence in a separate state, and that it makes no addition to the gravity of bodies, &c.

On the contrary, many other philosophers, and some modern chemists, are of opinion, that heat is a particular fluid, diffused through all nature, of which every body contains more or less. They distinguish that fluid as existing in two different states,—in combination, and at liberty. In the former state, it neither affects our senses nor the thermometer, but remains quiescent in those bodies of which it constitutes a principle; it is then more or less in a state of confinement. In the decomposition of the bodies it is often disengaged, and escapes into a state of liberty: it now becomes capable of acting on bodies exposed to its influence; and its force is measurable by a graduated thermometer. As all bodies that pass from a solid to a fluid state, and from thence into a vaporous form, excite cold in the surrounding atmosphere, they suspect that such bodies absorb a great quantity of heat; and when fluids, by assuming a concrete form, generate heat, they think that heat is then disengaged from those substances, and passes from a state of combination into a state of liberty.

Scheele, as well as Bergman, being persuaded that heat is a distinct substance, has examined with great attention all the phenomena which it displays as a chemical agent susceptible of combination. He has even thought himself warranted by his experiments to conclude, that it is a combination of vital air, which he calls *empyreal fire*, and fixed fire or phlogiston, and differs from light only in the relative quantity of the last principle. But however ingenious and accurate his experiments, the inductions which he has drawn from

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from them concerning the nature and principles of heat, do not appear to be naturally deducible from the facts; and we cannot consider his analysis of heat as fully demonstrated to be just. Some philosophers are of opinion, that light and heat are the same substance, only existing in different states. This substance becomes light, when its particles being collected together, and possessing all their attractive force, are violently darted to a distance: it assumes the character of heat, when the same particles exist in a state of division, move gently, and tend towards an equilibrium. Heat may be converted into light, and light again into heat. It must be acknowledged, however, that light often produces effects very different from those of heat; as on the nitric acid, the oxygenated muriatic acid, the calces or oxides of metals, and the leaves of vegetables dipped in water; all of which bodies afford vital air or oxygenous gas when exposed to the rays of the sun, which can be obtained from scarce any of them by the operation of heat. Thus the artificial light of our fires in passing through vessels, changes the nature of the products which it disengages. Lastly, Messrs Lavoisier and De la Place seem to think both these opinions true: they consider heat as a distinct substance, which by its presence in natural bodies occasions an oscillation of their component particles.

But though the nature of heat be not certainly known, the phenomena to which it gives rise in chemical combinations and decompositions are not the less certain on that account, and are worthy of careful observation. It appears from a vast variety of facts, that whether a body or a modification, it is of itself liable to no alteration, and is never lost; and the consideration of this has induced Messrs Lavoisier and De la Place

Place to form an axiom or general principle concerning its appearance or disappearance. As that axiom is of the highest consequence, we shall insert it here.

“ If in a combination, or in any change of state whatsoever, there be a diminution of free heat, the whole of that heat will again appear when the substances are restored to their former state; and on the contrary, if in any combination or change of state there be an increase of free heat, this additional heat will disappear when the substances return to their original state.”

They generalize this principle still farther, so as to make it extend to all the phenomena of heat; and they then express it in the following terms. “ All the variations of heat, whether real or apparent, that any system of bodies can suffer, are reproduced in an inverse order when the system returns to its original state.”

In order to measure the quantity of heat that is absorbed or disengaged in the various phenomena of chemistry, which appears from what has been said to be an object of the highest importance; modern philosophers have endeavoured to find means for correcting the observations of the thermometer, and extending its scale. M. Wilcke proposed to estimate the heats of bodies by observing what quantities of snow they could melt in a given time. Messrs Lavoisier and De la Place have contrived a method which is more certain and more easily practicable; reducing substances that produce heat by their combination, as well as the vessels in which they are contained, to the temperature of 32° Fahrenheit; they then put them into a vessel laid round with ice; and as the interior surface of the ice cannot be melted but by the heat which is disengaged while the substan-

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ces are entering into combination, the quantity of the heat thus disengaged may be measured by the quantity of the water obtained by the melting of the ice, which must be carefully collected *. By this process they have been able to estimate the specific heats of various bodies, to measure the quantity of heat absorbed in various combinations, and even to determine how much is disengaged in combustion and respiration. We are obliged to refer our readers to the work of those learned academicians themselves, for an account of this ingenious instrument, and the manner in which it is to be applied to the various purposes for which it is adapted; as the detail of particulars necessary to explain it would be inconsistent with that brevity which we mean to follow through the course of this work †.

Here let us consider more particularly the resemblance that appears in some instances between light and heat, as well as those peculiarities by which they are distinguished from each other in the operations both of nature and art. Though the light of the sun's rays warms those bodies on which it falls; yet we must not conclude from that circumstance that light and heat are the same; there are a great many instances in which light is totally destitute of heat, and others again in which heat is not accompanied with light; and a number of philosophers therefore consider them as essentially different. In fact, phosphori, diamonds,
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* We understand from the Philosophical Transactions, that in some attempts made by an ingenious Englishman, it was found that even this method may be fallacious.

† See a Memoir on Heat, read before the Royal Academy of Sciences on the 28th of June 1783, by Messrs Lavoisier and De la Place of that academy. A.

putrid wood, animal substances in a state of putrefaction, luminous insects and worms, as well as the rays of the moon, concentrated on metallic mirrors or lenses, afford a strong sparkling light, but no sensible heat: and all the bodies in nature may be strongly heated without becoming luminous.

The rays of the sun appear to produce heat merely by their impulse on the bodies on which they fall, or by the friction which they suffer from those through which they pass. Red, and more particularly black opaque bodies, are sooner heated than white, bright surfaces; doubtless because they refract the rays more powerfully, and perhaps even because light enters into combination with those high-coloured substances, while white surfaces do not absorb, but reflect the rays which fall upon them.

With regard to the production of light by a strong continued heat, as in the combustion of oils, wood, or grease, and the ignition of metals and stones; this may also be accounted for without allowing the identity of light and heat. When combustible bodies are strongly ignited, they at length produce flame; which has the same effects as the rays of the sun, and supplies their absence. But this light, which is produced by inflammation, may have before subsisted either in the combustible body or in the air, the presence of which is necessary to its production: and this fact, therefore, affords no proof that heat may be changed into light. The ignition of incombustible bodies, such as stones, in which light cannot subsist in a combined state, not at least in the same manner as in combustible bodies, has been very ingeniously explained by Macquer. In his opinion it depends on the strength of the vibrations communicated to the particles of those bodies by the im-

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impulse of heat. Those vibrations dispose the particles in such a manner, that their facets, acting like so many little mirrors, reflect upon our eyes the rays of light, which exist in the air by night as well as by day; for we are involved in darkness during the night, for no other reason but because these are not then so directed as to fall upon our organs of sight. Such were the notions of Macquer and of many other philosophers. But a very numerous series of accurate facts concerning the differences of heat in bodies, the capacity of bodies to absorb it, and the elective attractions to which it is subject, render the existence of heat as a distinct body much more probable than ever. It is thought to be often a principle in compound bodies, and the lightest of all the substances in nature; and this last property is considered as the reason why we cannot determine its existence by its weight. Heat is distinguished into two kinds, or rather as existing in two different states; in the one, it is intimately combined with other principles, and is denominated *latent heat*, or the *caloric* principle, because it is not perceptible to the senses; in the other, it is only diffused without combination. This last kind of heat may be expelled by pressure: thus, when a bar of iron is struck, the stroke compresses its particles and causes the heat to issue out, in the same manner as water issues from a wet sponge when it is pressed together with the hand. Combined heat cannot be separated from the bodies of which it forms a part, but by means of new chemical combinations. All solid bodies that contain any portion of these two kinds of heat, are capable of receiving more of both. When you add a quantity of the second species to any body, its first effect is to enlarge the pores that separate its component particles, by which means it softens

tens a solid ; next, as it gradually accumulates, it produces fusion or liquefaction ; and as the quantity of heat continues to increase, elastic fluidity follows : But we shall treat of these phenomena in the two following sections.

§ III. *Of Rarefaction.*

RAREFACTION is the most remarkable of all the effects which philosophers ascribe to fire, and is constantly produced by heat. We have already taken notice that the chief effect of heat is to diminish the specific gravity of bodies, by extending their bulk, without adding any thing to their absolute weight. This rarefaction shows, that some new substance is introduced into the cavities of the rarefied body. This substance, which is no other than heat, acts in proportion to the interstices which separate the component particles of the body. Bodies when rarefied by heat gain no additional weight, and have their specific gravity diminished ; because rarefaction consists simply in the separation of the parts of the warm body, its pores being enlarged, so that there is more vacuity and less solid matter than before in a given space. That separation of parts is effected by heat, which is to us, in point of weight, a mere non-entity.

When we consider, that the particles of bodies rarefied by heat, suffer an internal motion, which tends to divide them from one another ; and that cold, on the contrary, compresses and condenses them ; we are led to consider heat as a force opposed to the mutual gravitation

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vitiation of those particles, which weakens their particular attraction: For it is to be observed, that there are three modifications of the Newtonian attraction which ought to be carefully distinguished from one another. The first state of attraction is that which cooperates with a primary impulse to retain the planets in their orbits, preventing them from approaching the sun, upon whom they would soon fall were it not for the centrifugal force which they have received from primary impulse; this may be called *planetary attraction*, to distinguish it from the other two. The second state or modification of attraction is that which causes bodies projected into the atmosphere of our globe to tend towards the centre: this is *terrestrial gravitation*. The third modification of this general force is that by which the several parts of any body tend to their common centre; such as a stone or any other consistent body: this force produces aggregation, and in its various degrees is the cause of specific gravity: It is this last species that heat diminishes and tends to annihilate; and by acting in opposition to this force, it produces an infinite variety of effects in combination, decomposition, vegetation, animalization, &c.

Boerhaave, who has examined the effects of fire rather as a philosopher than a chemist, has established three general laws concerning rarefaction, which we shall examine.

FIRST LAW.

All bodies are dilated by heat.

THOUGH it be a general truth, that heat dilates and rarefies almost all natural bodies, yet we may make a few remarks on this phenomenon. First, all mineral substances without exception are dilated and rarefied in the direct proportion of the strength of the heat to which they are exposed. This rarefaction may even be carried so far as to destroy the aggregation of many among them; but vegetable and animal substances afford some exceptions to this law. A gentle heat indeed dilates their fibres, divides them, and thus diminishes their consistency; but a sudden strong heat causes parchment, membranes, and tendons, to shrink and contract their bulk, which seems to be occasioned by the irritability, or more properly the contractive force, of animal fibres, on which heat appears to act as a stimulus, till their organization be destroyed.

SECOND LAW.

All the dimensions of bodies rarefied by heat, are dilated.

A BAR of iron ignited becomes both longer and thicker. Philosophers have contrived several instruments for estimating, and even for measuring precisely this effect of rarefaction. The pyrometer invented by Muschenbroek, shows, by the dilatation of ignited bar

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of metal, so accurately as to distinguish the 1080th part of an inch. The communication of the expansive motion through various levers, whose arms are of unequal lengths, occasions this nice sensibility. The last of these moves through so large a space, that it easily indicates, by means of a hand or index carried round by a wheel, the extremity of which points to a series of numbers arranged round a circular plate of metal, the smallest degrees of dilatation that the bar suffers. As the pyrometer measures only the lengthening of bars of metal, philosophers have made an experiment with a cylinder, which passes through a ring when both are cold; but when the cylinder is heated the ring cannot contain it; and it thence appears, that the diameter of bodies is dilated as well as their length.

On account of this fact, which is well known to chemists, it becomes necessary to leave room in the grates that are placed in furnaces, and not to crowd vessels exposed to heat too closely together; otherwise you are in danger of having them broken, and suffering various other inconveniences in your processes.

THIRD LAW.

The dilatation of bodies is in the direct ratio of their rarity, or the inverse ratio of their density.

BOERHAAVE laid down this law after comparing the effects of heat on no more but three solid bodies very different from one another, wood, stones, and metals. He had observed, that in proportion to their densities wood was the most dilated by the same degree of heat, stones next, and after that metals. From this he ven-

tured to conclude, that the more rare the consistency of any body, the more easily is it dilated; and that the greater the density of a body, the less is it liable to rarefaction. But by examining the rarefaction produced by heat on a great number of bodies, M. Buffon has found that the dilatation of solid bodies by heat is in direct proportion to their alterability by fire; stones are dilated in proportion as they are susceptible of calcination, and metals in the ratio of their fusibility. Boerhaave had likewise extended this law to fluids, without examining the dilatation of any fluid bodies but air, spirit of wine, and water. Had he compared the rarefaction of mercury with that of these bodies, he would scarce have ventured to lay down this general law. For mercury; though its density be greatly superior to that of water or spirit of wine, admits of much easier dilatation than either of them. And from this fact it appears that the quickness or slowness of the rarefaction of fluids by heat depends on neither their inflammability nor fusibility. Messrs Lavoisier and Bucquet, who have made a long train of experiments on the dilatation and rarefaction of bodies by heat, have found themselves unable to determine the cause of that amazing diversity which appears among those phenomena, and have contented themselves with describing their experiments, without presuming to deduce any induction from them.

Besides these laws of the rarefaction produced by heat, which are still but very imperfectly known, it is of importance to know, 1. That bodies always produce cold when they pass from a solid to a fluid state; as for instance, salts when dissolved in water evaporating æther, &c. 2. That fluids capable of assuming a concrete form, generate heat as they become solid: thus

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water, which freezes when put into a freezing mixture, never affords so high a degree of cold as spirit of wine put into the same mixture. It may be understood from what has been said, that when a solid body becomes liquid, it absorbs an additional quantity of heat; and when a liquid body becomes solid, part of the heat which it contained is disengaged.

§ IV. Of the Phlogiston of Stahl.

BECCHER, struck with that property of certain bodies which enables them to produce fire, that is to say light and heat, in consequence of continued motion, or by coming into contact with other bodies in a state of ignition, imagined it to depend on a distinct principle, to which he gave the name of *inflammable earth*. Stahl, whose attention was strongly engaged by this doctrine, understood this principle to be pure fire, or the matter of fire, fixed in combustible bodies. To this element, existing in such a state of combination, he gave the name of *phlogiston*, or the *inflammable principle*, to distinguish it from fire in a free or active state. Its properties, when combined, are totally different from those which it displays when at liberty: it then gives neither heat nor light, tho', in the latter state, these are its constant attendants: But, when freed from confinement, it instantly regains its characteristic properties, and its presence is indicated by both heat and light. Such was the sublime and simple idea of Stahl concerning the nature of combustible bodies. It is indeed natural to think, that those substances which, when strongly heated or forcibly

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struck, become inflamed, and continue to burn till they be consumed, owe this property to their latent fire; and that the combustion of such bodies is nothing but the disengagement of the fire, and its passing to a state of liberty. According to Stahl, therefore, all combustible bodies contained fire in a fixed or combined state, on which principle their inflammability depended. He also considered this principle as being perfectly the same in all the substances into which it entered, whatever their nature, or however different they might be from one another. The combustibility of any body appeared to him a sufficient proof that it contained a quantity of phlogiston. Thus, in his opinion, sulphur, charcoal, metals, oils, and phosphorus, owed all their properties to phlogiston; and their differences in point of form, colour, consistency, gravity, &c. might depend, he thought, on the variety of the principles to which the phlogiston was united; for the phlogiston itself was always the same, and could suffer no variation but by being dismissed from a combined into a free state.

In order to distinguish the properties of phlogiston or fixed fire, Stahl instituted a comparison between bodies into the composition of which it enters, and others that seem destitute of it. He observed the former to possess in general, colour, smell, fusibility, volatility, and combustibility; while he found the latter to be commonly destitute of colour and smell, fixed in a greater or less degree, incapable of fusion, and still more incapable of combustion. He likewise observed, that such bodies as evidently appeared to be phlogistified, lost most of their properties when deprived of their phlogiston, but regained them when it was restored.

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He applied his doctrine chiefly to sulphur and metallic substances: the phenomena which these afforded were the leading facts on which it was established. Metals he considered as compounds of certain earths with phlogiston. When calcined, their phlogiston is disengaged, and escapes into a state of freedom; and they lose, of consequence, their fusibility, ductility, and inflammability. You may cause them to recover these properties by heating them with oils, charcoal, or any other phlogisticated substance, so as to restore to them what they before possessed of that principle. Sulphur is a combination of the sulphuric acid and phlogiston: its combustion consists in the disengagement of the latter principle; and when this is entirely disengaged, nothing but the acid remains. By applying charcoal, oils, or metals to this acid, we can deprive them of a part of their phlogiston; which being communicated to it, forms a new quantity of sulphur, or a coloured, odorous, fusible, volatile, and inflammable body.

However plausible this theory may be esteemed, yet, in considering it, one important difficulty occurs: Stahl and his followers have never told us precisely what phlogiston is, but have always expressed themselves on that head in obscure and indeterminate terms. Macquer, who was sensible of this difficulty, after having long considered the nature of fire and phlogiston, concluded that light possessed all the properties ascribed to it, either when in a state of freedom and activity, or when united with other principles in compound bodies, and labouring to disengage itself. When we exhibit a view of a theory that has obtained a place in science, it is but fair to point out what difficulties attend it, and to examine whether it be founded

ded in error, or on the solid basis of truth. We shall, therefore, mention the objections that are now made to the doctrine of that great chemist; a doctrine which has now lost its lustre, after having long made an illustrious figure in the science.

The leading difficulties which occur in considering the theory of phlogiston may be reduced to three heads: 1. The properties which Stahl attributes to that principle do not always appear in the bodies in which he supposes it to exist. Charcoal, and particularly that of resinous bodies, which he considers as pure phlogiston, is neither odorous, volatile, nor fusible: there are even some species of charcoal which are scarce combustible. Diamond, an extremely fixed, transparent, inodorous, and infusible substance, is perhaps the most combustible body known, as it burns entirely, without leaving any residue. Spirit of wine, æther, and several of the essential oils, are without colour.

2. Many bodies, upon losing their phlogiston, acquire new properties, which Stahl considered as depending upon that principle. Most metals, when calcined, assume a deeper colour; cobalt, mercury, lead, iron, copper, &c.

3. Stahl paid so much attention to combustible bodies, as he hoped, from the examination of their nature, to determine the character of phlogiston, that he seems to have forgot that air is essentially necessary to combustion. In consequence of this, he has overlooked this objection against his theory, which was not indeed urged against him by any cotemporary chemist. If combustion be nothing but the disengagement of phlogiston, it is plainly an act of decomposition, in which the combustible body loses one of its principles:

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But how is it possible for a body, after having lost one of its component principles, to possess considerably more absolute weight than before? An hundred lib. weight of lead affords an hundred and ten of minium; the weight of the sulphuric acid obtained by the combustion of sulphur, is greater than that of the sulphur from which it was obtained: and, in the same manner, we learn from the fine discovery of M. Lavoisier, that eighteen ounces of pure water are obtained by burning sixteen ounces of spirit of wine*.

The strength of this objection, together with the difficulty that is found in every attempt to demonstrate the existence of phlogiston, have induced some modern chemists to deny that there is such a substance in nature. But they must not be implicitly listened to; even that numerous train of experiments which have been of late made on combustible bodies and combustion, have not fully demonstrated that there is no such principle as fixed fire in material bodies: its existence seems to be allowed, while its name is changed; and instead of the phlogistic, it is called the *calonic*, principle. It is divested, however, of the property of producing combustion; and though it be allowed to exist in inflammable bodies, it is not considered as the cause of their inflammability.

Since chemists began to enquire how far the presence of air is necessary to combustion, they have made several important discoveries; the chief of which is, that a certain quantity of atmospheric air is always absorbed by burning bodies, and that it is the acquisition of this air, which becomes fixed or combined, that augments the absolute gravity of metals, sulphur, phosphorus,

* Meeting of the Royal Academy of Sciences on the 4th of September 1784. A.

phorus, inflammable gas, and spirit of wine, when exposed to combustion. As this increase of gravity has been likewise found to correspond precisely with the weight of the air absorbed, several chemists, at the head of whom may be reckoned Messrs Lavoisier and Bucquet, were led to adopt a new theory, founded solely on this absorption of air, in which they entirely rejected phlogiston. This theory was directly opposite to Stahl's, and consisted of the four following principles:

1. Stahl's phlogisticated bodies are, according to this doctrine, substances which have a strong tendency to combine with air; for on this tendency the combustibility of bodies entirely depends.

2. All the phænomena which Stahl ascribed to the disengagement of phlogiston are produced by combinations with pure air: such are combustion, calcination, respiration, and the formation of the sulphuric and phosphoric acids, by the combustion of sulphur and phosphorus.

3. On the other hand, according to the pneumatic theory, all those phænomena in which the doctrine of Stahl represents the phlogistic principle as entering into new combinations, are produced by the disengagement of air. Such are the reduction of metals, effected by the mutual action of metallic calces and charcoal, the decomposition of acids by combustible bodies, and particularly the decomposition of the sulphuric and the nitrous acids by iron, charcoal, &c.

4. This theory views all those bodies which Stahl thought to be compounds, with phlogiston for one of their principles, as simple substances, having so strong an affinity with pure air, that they attempt to enter into combination with it whenever they are exposed to

its contact. Combustion is, therefore, nothing but the combination of air with the combustible body; and all operations in which bodies are thought to regain their phlogiston, are merely the disengagement of pure air, or its passing out of one body into another.

This opinion, which was adopted by M. Bucquet in his latter courses of lectures, explains indeed most of the phænomena of combustion, calcination, and the reduction of metallic calces; but it gives no satisfactory reason why flame is seen to proceed from combustible bodies in a state of ignition; nor does it account for the rapid motion produced in inflammation, and the other changes which attend that phenomenon. Macquer, after carefully examining how far the modern discoveries could affect the received theories, was of opinion that they were insufficient to explode the theory of Stahl, and has therefore combined the pneumatic with the phlogistic doctrine, by representing phlogiston as light in a state of fixation. After showing that pure light, such as that which the sun diffuses over our globe, may be considered as the genuine substance of fire, and, by being fixed in bodies, may actually constitute the phlogiston of Stahl; he next gives it as his opinion, that in every act of combustion, pure air disengages the light or phlogiston of combustible bodies, and possesses itself of its place; and that the calcination of metals may therefore be regarded as the precipitation of air, and the disengagement of light. Again, when phlogiston is restored to the calces of metals by reduction, light, in its turn, disengages or separates the air which was fixed in those substances, and by that means causes them to resume the character of metals. Macquer also thought, and it was necessary
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to this theory, formed with a view to reconcile Stahl's with the modern doctrine, that phlogiston may combine with bodies even in close vessels, since light is well known to penetrate through glass, and even through metal and earthen vessels, when these are made red-hot. Scheele has proposed a different theory, which has also been adopted by some northern chemists. He considered fire, heat, and light, as compounds of vital air with phlogiston; and thought that light, in passing through vessels, suffered decomposition, the phlogiston in the reduction of metallic calces or oxides being communicated to the calx, while the vital air was disengaged. But that ingenious theory, by which Scheele accounted for the effects of solar light, and of the various modifications of heat on a great many chemical phenomena, affords no explanation of the increase of the weight of metals, sulphur, and phosphorus, &c. after combustion.

M. Lavoisier, whose experiments have contributed so highly to the advancement of chemistry, and whose opinion must therefore have considerable weight, has proposed a new theory that has been adopted by most French chemists, and appears to me to afford an happier explanation of the phenomena of Nature than any other. He thinks that light, heat, and all the other remarkable phenomena of combustion, depend rather on a certain action of the air than on the peculiar nature of combustible bodies; that the flame which then arises is occasioned by the disengagement of the light which was combined with the pure air, not of that which existed in the combustible body. He ascribes to pure air that decomposition which, according to Stahl and Macquer, takes place on the inflammable substance. Pure air he considers as a compound of the substance

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of fire and another principle which shall be afterwards described; and fixed fire, the disengagement of which is the principal act on such occasions, is, in his opinion, separated from the pure air, not from the combustible body. We cannot enter more particularly into this ingenious system in this place. In the history of air, in the following chapter, it will come more properly under our examination. At present, we will content ourselves with observing, that fire or heat, which M. Lavoisier allows as a principle of pure air, and the disengagement of which he takes to be the cause of the sparkling flame and vivid heat which accompany the rapid combustion produced by that air, act nearly the same part with Stahl's phlogiston, or Macquer's fixed light; and that chemists seem to be universally agreed concerning the existence of this principle, the only difference among them being, that one party believe it to exist in combustible bodies, and to be the cause of inflammability; while another consider it as a principle of air, and ascribe inflammation to a different cause. In the following chapters, we shall explain the reasons which induce us to prefer the latter of these opinions.

V. The Effects of Heat on Bodies considered Chemically.

IN the third subdivision of this chapter, it was shown that one of the chief effects of heat is to rarefy bodies, to increase their bulk, and diminish their specific gravity, by separating their particles, and enlarging their pores. Such was the simple physical or mechanical idea which we gave when speaking of rarefaction

in general ; but when we attend more carefully to the primary act of heat, we shall find that it produces several other important effects.

The first and most striking effect of heat, is its diminishing the aggregation of bodies, by separating their particles. As the force of aggregation, and that of the attraction of composition, are always in the inverse ratio of one another, as has been shown in the third chapter, it will be readily understood that heat, in destroying aggregation, must be singularly favourable to combination. This has caused fire to be considered as the principal chemical agent, and has even induced chemists to assume the title of *philosophers by fire*. It will afterwards appear, however, that they make much less use of it at present than they formerly did.

The action of heat, when considered in this point of view, as tending to destroy aggregation, and favouring combination, appears liable to four different modifications, according to the nature of the bodies on which it exerts its energy.

1. There are some bodies on which it produces no alteration, nor any effect but dilatation. Substances of this nature are unalterable and *apyrus*. Thus rock-crystal, however long exposed to the utmost violence of fire, suffers no alteration : it loses neither its hardness nor transparency, and appears, after this assaÿ, with all its former density and beauty. But there are very few substances so little alterable as rock-crystal.

2dly, Heat entirely destroys the aggregation of most bodies, causing them to pass from a solid to a fluid state. This phænomenon is named *fusion* ; the bodies on which it is produced are called *fusible*. There are various degrees of fusibility, from that of platina, which is extremely difficult to melt, to that of mercury which re-

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remains always in a fluid state. When this fusibility is carried to an excessive degree, it becomes volatilization. A body becomes volatile, or diffuses itself through the atmosphere, when it is caused to pass, by a strong rarefaction, from the liquid state to that of an elastic fluid. It is then dissipated by heat, and elevated in the atmosphere, where it remains suspended till cold restore to it part of its density and specific gravity. Bodies which may be reduced to this state are named *volatile*; those incapable of it are, by way of opposition, called *fixed*. There are many degrees between fixity and volatility. It even seems impossible to suppose any body absolutely fixed. Perhaps the only reason why any appear so, is, because we cannot apply to them a degree of heat sufficiently intense. We may make the same remark on infusibility; it is never absolute. The reason why rock crystal appears infusible, is, because we cannot apply to it the proper degree of heat. When we speak, therefore, of the infusibility or the fixity of certain substances, we are to be understood as speaking only in reference to the heat to which it is in our power to subject them.

This essential volatility is to be carefully distinguished from that which is merely apparent, and takes place only in consequence of the communication of motion by a current of flame or vapours: Thus, for instance, iron, in a state of calcination, is carried up by the flame that is raised during its combustion.

3dly, When heat acts on bodies consisting of two principles, one volatile, the other fixed, it generally separates them by volatilizing the former. Such bodies are thus decomposed, but without suffering any alteration; for by reuniting their principles, we can reproduce them with all their original properties. This

separation of principles is a true or simple analysis. Fire applied to bodies consisting of two substances, between which there is a wide difference in respect of volatility, reduces the volatile principle to vapours, but leaves the fixed uninjured. But in order that this true analysis may take place, it is requisite that both the volatile and the fixed principle of the compound be unalterable by the degree of heat applied to them; or that they be exposed only to such a degree of heat as they can bear without losing any of their properties. The volatilized substance having then undergone no greater alteration than the fixed, they may be reunited so as to form the same compound which they constituted before their separation. When this may be effected, the analysis is true or simple. As bodies do not generally consist of two principles, one of which is volatile the other fixed, and as it is often extremely difficult, and sometimes even impossible, to apply to compounds of this kind precisely that degree of heat which will volatilize the one without alteration, and leave the other uninjured; it may be naturally inferred, that the number of the bodies on which heat acts in this manner must be very inconsiderable. For this reason, chemists have now much less frequently recourse to the operation of fire than formerly. The substances on which heat produces this effect are *decomposable without alteration*. Some mineral substances, such as crystallized salts and solutions of neutral salts, come under this class.

4thly, When the body exposed to the action of fire consists of several volatile and several fixed principles, the volatilized principles enter into mutual union; the fixed are also combined with one another: and such is the result of this decomposition, that though the pro-

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ducts be reunited with the residues, the original compound will not be produced. -This is therefore a false or complicated analysis. The bodies on which heat acts in this manner are *decomposable with alteration*.

Most natural substances belong to this class. They are too complex in their composition, and consist of too many principles, to be decomposed without suffering alteration. As the force of the affinity of composition acts upon all bodies, and is even promoted by heat, when any of the principles of a compound are volatilized by the action of fire, they react upon one another, unite, and form a new order of combination different from that in which they before subsisted: the same thing takes place on the fixed principles of the body. Thus, when a piece of wood, bark, or any other vegetable substance, is exposed to the action of fire, the water, the salts, and the oil, unite together, and constitute an acid, elastic fluids, and a brown oil, &c. which did not exist in the wood in that form. The action of heat, therefore, produces a total alteration on such substances: the phænomena which attend it indicate a false or complicated analysis, the results of which might lead chemists into mistakes were they not aware of the uncertainty with which it is attended. It is certain that art can never reproduce wood or bark, by mixing together the phlegm, oil, acid, and charcoal obtained in this analysis, and that the principles which it affords have suffered great alterations. Unluckily the bodies susceptible of these alterations are the more numerous class. Under it all animal and vegetable, and most mineral, substances are to be ranked. But the modern discoveries will enable us to determine the true nature of the principles of such substances, by examining such of them as are disengaged.

Hitherto we have spoken only of the effects of such

a strong heat as is usually employed in the operations of art : But a gentle and continued heat, such as that which is exerted in the operations of nature, gives rise to a number of important phænomena, which are highly worthy of the chemist's attention. The vibration and oscillation of the particles of solid bodies which its impulse occasions, and the agitation and rarefaction of fluids arising from the same cause, produce a continued internal motion which gradually changes the form, the dimensions, and the contexture, of the former ; and produces a sensible alteration on the consistency, the colour, the taste, and, in a word, on the intimate nature, of the latter. Such is the general idea which we have reason to form concerning the existence and power of all the chemical phænomena of natural bodies ; concerning the spontaneous decomposition and recombination of minerals ; concerning the crystallization, the solution, the formation of salts, the vitrification, the metallization, the vitriolization, and the mineralization, which are carried on in the bowels of the earth. To this powerful agent we must likewise have recourse, when we attempt to form an idea of the alterations to which animal and vegetable substances are liable ; of the motion of the sap in plants, and the mild fermentation which conducts them to maturity ; of the formation of oils, the spiritus rector, mucilages, and the colouring principle ; or of the composition, the decomposition, the reciprocal changes, and the putrefaction of animal humours. All these important phænomena depend, more or less, on chemical operations ; and that heat which is diffused over the globe is the great principle by which they are produced. It is at present enough for us to have taken a general view of the

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great cause of motion, life, and death. We have here sketched the outlines of the picture; in what follows we shall endeavour to fill them up with a nice and faithful hand.

As the various effects of heat depend all on its power of separating the particles of bodies, let us farther consider this first effect, and attempt to estimate its influence.

Water in the state of ice is softened by a certain degree of heat, melted, and reduced to fluidity by a greater, and by a still greater degree reduced to vapour, or an elastic fluid: so that water in a state of vapour may be said to contain three sums of heat;—that which constitutes ice of a certain density; that which reduces ice to the state of a liquid, rarefied to a certain degree; and, lastly, that which rarefies the liquid to an elastic fluid.

When we attempt to apply this theory to all natural bodies, they appear to be all capable of passing through these several states if exposed to a sufficient heat. The only difference among them, in point of this property, is, that some may be reduced by a less degree of heat while others require a greater. It is only for want of a sufficient heat that we cannot reduce rock-crystal to a liquid or a vaporous state: nor is it more difficult to conceive the possibility of this event, than to conceive an habitually elastic fluid, such as air, acquiring an extreme solidity, as happens to this very substance in various combinations.

From these principles, it is easy to explain the formation of the elastic fluids which are disengaged in many of the operations of nature and art. It uniformly happens, whenever a body receives and absorbs a sufficient quantity of heat to cause it to pass into that

state of fluidity which constitutes an aeriform fluid, and therefore all fluids that possess this property owe it to heat. But it is also requisite, that the pressure of surrounding bodies, especially the pressure of air, do not oppose this extreme dilatation; or that the dilatation be so great as to overcome the resistance which it meets with in the gravity of the air. Hence a body, whether nearer to or more distant from the state of elastic fluidity, may be easily reduced to that state by relieving it of the pressure of the atmosphere, as elastic fluidity always takes place in *vacuo*. Hence evaporation is most quick and copious on the tops of lofty mountains. And hence too it becomes necessary to mention precisely, in a detail of experiments, with what degree of pressure any body was reduced to an elastic fluid, or at least what pressure it can bear in that state: for it is also to be observed, that all the bodies which can, with more or less ease, be reduced to the state of vaporous or elastic fluidity, do not maintain themselves in that state with equal constancy; nay, such are the differences among them in this respect, that they have been divided into *permanent and non-permanent*. The former remain long in the state of elastic fluidity; nor do they pass from it, till by some new combination they are deprived of the substantial heat by which they were maintained in that state. The latter, which may be denominated vapours, lose their elastic fluidity by degrees of pressure or cold which may be easily estimated, and readily communicate to surrounding bodies that portion of heat which constitutes them aeriform fluids. Of this kind are water, alcohol or spirit of wine, and æther; these three fluids are reduced into vapours, and remain in that state when the barometer stands at 28 inches,—water at 185° Fahrenheit,

renheit, spirit of wine at 167° , and æther at 92° , &c. It appears then, 1st, That the state of elastic fluidity is a mode of the existence of bodies occasioned by the combination of heat with their other principles: 2^{dly}, That every elastic fluid is a compound, consisting of a base of more or less solidity and the matter of heat: 3^{dly}, That the base of every elastic fluid requires a certain degree of heat to reduce it to vapour or elastic fluidity; and that it is doubtless in consequence of their possessing these properties, that elastic fluids differ in gravity, elasticity, &c.

M. Lavoisier has explained this theory with great perspicuity, in a memoir printed among the Memoirs of the Academy of Sciences for 1777.

Although we have distinguished elastic fluids into permanent and non-permanent, yet it is to be observed, that this distinction exists not in nature. It is relative to the moderate heat and pressure of the atmosphere to which we are exposed in the climates in which we live, and over many parts of the globe; and if the cold and pressure were more considerable, even the fluids which we at present consider as the most permanent, would soon cease to be so; and, on the contrary, æther and spirit of wine would become permanent elastic fluids at a certain height in the atmosphere, or in the warm temperature of the equatorial climates.

As the substance of heat, which contributes to the formation of elastic fluids, exists in them in a combined or *latent* state, and becomes not perceptible to our senses till those bodies lose their fluidity by entering into combination with other substances; we have therefore sought for an expression proper to denote heat in this state, and have adopted the word *caloric* for that purpose; because in this state heat may be actually

considered as having lost its original character, which it recovers not till it be restored to a state of liberty. Besides, by affixing to it this denomination, we avoid the circumlocutions of the substance or matter of heat, or latent heat, which have been hitherto applied to it. Cooling, or the passing of heat into the state of caloric, and ignition, or the passing of caloric into the state of heat, depend both on the general law above laid down, that when bodies become more dense, part of their heat is exhaled. Thus, whenever a gas or aeriform fluid is combined so as to become a liquid or a solid, it loses a great part of its substantial heat; and to make it pass into that state of density, it must be exposed to the action of some body, with which its base has a greater affinity than with heat. This is the general cause of the fixation of elastic fluids; and in this manner do they lose that form by becoming fixed in liquid or solid bodies. We may likewise observe that each of these fluids loses more or less heat in proportion as it becomes more or less solid in the new combination, or in proportion as that compound body is capable of containing less or more specific heat. This observation explains why bodies burn with different degrees of rapidity; why they give during combustion more or less flame or heat; and why the residues which they leave are more or less solid, &c.; which phænomena shall be more particularly mentioned in the following chapter.

Lastly, Since cold and pressure are the two means by which elastic fluids are condensed, we may perhaps be at length able, by employing intense degrees of both, to reduce all these from their gaseous state, and to obtain their bases pure and separate, by expelling the substantial heat which maintains them in fluidity. Thus we may come to know the bases of vital air, azotic or

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mephitic gas, hydrogenous gas, &c. This has been already performed on the sulphureous acid gas, which M. Monge has reduced to a liquid by means of an intense cold.

§ VI. *Of Heat as a Chemical Agent, and the several Ways in which it may be applied to Bodies.*

CHEMISTS employ heat, on account of the changes which it produces on bodies, both for decomposition and combination. Their first object should be to measure exactly the degrees of heat necessary to produce all possible alterations on any body exposed to it. These degrees of heat are generally ranked under two classes; the first comprehending all degrees of heat below that of boiling water; the second, all above that temperature. The scale of the thermometer marks out the former; our only means of determining the latter is the known fusibility of bodies.

Degrees of Heat below the point of boiling Water.

THE first degree extends from 44° to 53° Fahrenheit's scale*. This temperature promotes putrefaction, vegetation, and gentle evaporation, &c. It is but seldom employed in chemical operations, as being too inconsiderable; in some macerations made during winter, however, it is necessary. It is likewise useful for the crystallization of saline solutions, which after a proper evaporation are put into caves, or other places of this temperature.

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* Reaumur's scale is used in the original.

The second of these degrees, extending from about 61° to 70° , continues to promote putrefaction, excites a spirituous fermentation in saccharine liquors, and is favourable to evaporation and slow crystallization. This is the usual temperature of mild climates. It is employed for maceration, the solution of saline substances, and fermentation, &c.

The third division or degree extends from about 79° to 88° . It excites the acid or acetous fermentation in vegetables; and is sufficient for the exsiccation of plants. It is used to effect some solutions of salts, and to produce fermentation.

The fourth degree, which rises to 114° , is called the mean degree of hot water: this is the heat used in the vessels called *balnea mariæ*. It destroys the organization of animal substances, and volatilizes the subtler part of animal oils, more especially of the spiritus rector. It is employed in the distillation of those vegetable and animal substances, of which we wish to obtain the phlegm and the odoriferous part.

The temperature of boiling water 185° , is used in decoctions, and the extraction of essential oils.

Degrees of heat above the boiling point.

THE first degree or division makes glass red, burns organized substances, and melts sulphur.

The second melts the softer metals, tin, lead, bismuth, and such glasses as are most easily reduced to a state of fusion.

The third effects the fusion of moderately hard metals, such as zink, regulus of antimony, silver, and gold.

The fourth burns porcelain, and melts the more refractory metals, cobalt, iron, and copper, &c.

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The last and most intense degree exists in the focus of a burning-glass. This temperature calcines, burns, and vitrifies in an instant, all bodies susceptible of combustion, calcination, or vitrification. A similar heat may be excited by pouring from a blow-pipe a stream of vital air or oxygenous gas upon a piece of coal. M. Monge is of opinion, that by presenting to combustible bodies, when in a state of inflammation in a furnace, a quantity of compressed atmospheric air, the same effect might be accomplished which is produced by vital air. This process may be one day or other applied to very important purposes.

Though these degrees above the heat of boiling water be determined by phenomena which are well known to chemists, yet they have not hitherto been measured with all the precision that could be wished. It is therefore an object of the utmost importance to obtain an instrument capable of pointing out the exact degrees of heat employed in these operations. Mr Wedgewood in England has constructed a thermometer for this purpose: it consists of small pieces of clay half an inch in diameter. These pieces, when contracted by the heat, fall between two graduated rulers of copper inclining towards each other upon a plate of the same metal; and thus show what contraction they have suffered, and of consequence to what degrees of heat they have been exposed (*Jour. de Phys. Ann.* 1787. *)

The heat necessary in chemical operations is produced by burning charcoal, or common mineral coal. We use on those occasions furnaces of different forms and names, according to the different purposes for which they are intended; such are the furnaces for digestion and

* There is an accurate description of this ingenious contrivance, by the inventor himself, in the English Philosophical Transactions for 1782.

and fusion, the reverberating furnace, the wind furnace, and the cupelling furnace. A single furnace, properly made, is often sufficient for the purposes of all all these; and it is then called a *Polychrest furnace*. The reader may consult on this head the Chemical Dictionary of Macquer, who has contrived a most excellent and useful furnace; Baumé's Chemistry, Pott's Lithoegnoscia, and Abbé Rozier's *Journal de Physique*, in which there are descriptions of various furnaces constructed by different chemists. The flame of oil, or spirit of wine, is also employed sometimes in lamp-furnaces adapted to the purpose.

The manner in which fire is applied to bodies in chemical processes, likewise deserves some explanation. If the combustible body be applied immediately to the substance on which you wish the fire to act, the operation is then said to be managed with *naked fire*. But some intermediate body is often put between the fire and the substance exposed to its action; hence the names *balneum mariæ*, sand-bath, cinder-bath, dung-bath, &c.

The form of the vessels made use of in subjecting bodies to the action of fire, and the various phænomena exhibited by bodies under the influence of heat, have caused a great variety of operations to be distinguished by peculiar names. Such are roasting, calcination, fusion, reduction, vitrification, cupellation, cementation, stratification, detonation, decrepitation, fulmination, sublimation, evaporation, distillation, rectification, concentration, digestion, infusion, decoction, lixiviation. All these operations are performed by the action of fire, and enter into the practice of chemistry; and we shall therefore give a short explanation of each of them.

Roasting is a preliminary operation, which prepares

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mineral substances for undergoing a series of succeeding ones, dividing their constituent particles, volatilizing some of their principles, and producing a certain alteration on their nature. Mineral ores are exposed to this process on purpose to separate the sulphur and arsenic which they contain, and to diminish the cohesion of their particles. Capsules of earth or iron, crucibles, and roasting pots, are the vessels in which it is usually performed; and it is generally exposed to the access of the external air. Sometimes, however, the operation is performed in close vessels; and two crucibles, luted mouth to mouth, are commonly employed on such occasions.

Calcination is, as it were, a more advanced stage of the process of roasting. By this process minerals are deprived of their water and salts; it likewise reduces calcareous substances to the state of quick-lime, and metals to metallic oxides. The same vessels are used in this process as in the former.

In fusion, a body is caused to pass by fire from a solid to a fluid state. The chief subjects susceptible of this operation are salts, sulphur, and metals. Crucibles of baked clay of various kinds and figures, with metallic cones and ingot moulds, are the instruments for this operation. These last are employed to give the melted matter a certain form; which they mould into bars, ingots, or buttons.

In reduction or revivification, the calces of metals are, by means of fire, with charcoal or oils, restored to the metallic state which they lost by calcination.

Vitrification is the fusion of such substances as are capable of assuming the brightness, transparency, and hardness of glass. Vitriifiable earths with alkalis, and
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the oxides of metals, are the chief of the substances subjected to it.

Cupellation is the purifying of perfect metals, by the extraction of such imperfect metals as are intermixed with them. This is performed by the addition of a certain quantity of lead to the mixture, and the exposing of it to a due heat; which vitrifies the lead, and together with it the imperfect metals of the original mixture, leaving the perfect in a pure and separate state. This operation derives its name from the vessels used in it. These are a kind of flat crucibles, pretty like the small cups known under the name of *cupels*; and the substance of which they are composed, being the earth of bones, is sufficiently porous to absorb and retain the lead that is scorified by the heat.

The name of *cement* is given to powdered substances, with which other substances exposed to their action are carefully covered over. Thus, iron is covered over with powder of charcoal, that it may be converted into steel; and glass with plaster or filex, to change it into a kind of porcelain. The process by which this is effected is cementation, and requires the action sometimes of a very strong fire.

Stratification is an operation nearly similar to the preceding. It consists in arranging several solid substances, usually in horizontal layers, and intermixed with certain pulverized bodies, to alter their nature, either in a crucible or in some other suitable vessel capable of bearing the action of fire. This has received the name of *stratification*, because the substances are disposed in strata or layers, one rising above another. Copper and silver are treated in this manner with sulphur, in order to effect their combination. This peculiar arrangement of substances named *stratification*, is often

often employed preparatory to fusion, calcination, vitrification, &c.

Detonation is peculiar to nitre, and the mixtures into which it enters. It is the explosion of such bodies when heated in open or close vessels. Decrepitation differs from detonation only as producing a fainter noise, which is merely a kind of crackling sound: it is peculiar to certain salts; which from a state of solution are crystallized so rapidly, that the crystals formed burst into minute pieces. This has been observed chiefly of common salt, or muriate of soda. Fulmination is a more quick and lively detonation; such as takes place on fulminating gold, fulminating powder, and in the combustion of inflammable gas and vital air, &c.

Sublimation is the volatilizing of dry, solid, and often crystallized substances by means of fire. The vessels used in sublimation are glazed earthen pots, earthen crucibles with glass heads, and pots of earth or porcelain, arranged one above another, and joined by the insertion of their necks one into another, which are known by the name of *aludels*, &c. Sulphur, arsenic, cinnabar, many mercurial preparations, some vegetable substances, more especially camphire and flowers of benzoin, are the subjects of sublimation.

Evaporation is the action of heat on liquids, to diminish their fluidity and quantity, and to obtain the fixed bodies dissolved in them in a separate state. Thus, we evaporate the water of the sea and of salt springs, in order to obtain the salt which they contain. This operation is performed in capsules, jars, earthen or glass evaporatories, and silver pans, according to the nature of the liquid to be evaporated. The evaporating substance is exposed to the contact of the air, in order that
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the water, the body to be carried off by volatilization, may diffuse itself through the atmosphere, and that the air by its solvent power may promote the evaporation.

Distillation is an operation nearly similar, but performed in close vessels. It is used to separate volatile from fixed principles by means of fire. The distillatory vessels are alembics and retorts. The first consist of a lower vessel named a *cucurbite*, intended to contain the body to be distilled, and an upper part or capital exactly fitted to it; the purpose of which is to receive the volatilized substance, and condense it by the coldness of its temperature (which is maintained by the contact of the external air, or of water surrounding it); when water is used, the vessel containing it, into which the upper part of the alembic is immersed, is called a *cooler*, or *refrigeratory*. From the lower part of the capital there proceeds a kind of beak or spout, through which the vapours pass into a pipe, where they are condensed into a liquid: from this pipe the liquid thus obtained is conveyed into other vessels, which are commonly of a spheric form, and are named *receivers*. These receivers are of various forms and names, *matrasses*, *balloons*, &c. A retort is a kind of glass, stone, or metal bottle, of a conical form, with its extremity bent, so as to make an acute angle with its body; and on this account has it received the name *retort*. Distillation has been rather improperly distinguished into three kinds, namely, distillation ascending, *per ascensum*; distillation descending, *per descensum*; and lateral distillation, *per latus*. This distillation is warranted only by the exterior form of the vessels made use of. The volatilized matter has always a tendency to ascension: But distillation performed in glass or metal alembics

bics has received the peculiar denomination of *ascending*, because the capital is placed over the cucurbite, and the vapours are seen to ascend. The distillation performed in retorts is called *lateral*, because the beak or neck of that vessel comes out at the side of the apparatus; but the cavity of the retort in which the vapours are condensed is higher than its neck, and the distilled substance passes through that cavity before reaching the neck. As to distillation *descending*, it was an operation which scarce served any purpose, and is now no longer used; its products were always in a very bad state, and great part of them was lost in the process. It was performed by spreading a piece of cloth over the mouth of a glass, placing upon it some vegetable substance, and covering this with the scale of a balance, or with a capsule of metal containing some live coals. This mode of distillation was formerly used in pharmacy and perfumery, for obtaining the essential oils of some odoriferous substances. The product passing through the cloth dropped into the glass, which was always half full of water, to cool the oil; but most part of the essence was always lost on the cloth and the metal plate above. A more useful distinction is that which regards the manner in which the substances to be distilled are warmed. This is performed either with the *balneum mariæ*, by dipping the cucurbite in boiling water, or with the vapour, the sand, or the cinder-bath, or with naked fire. It is also effected by means of the flame of a lamp, and by that of spirit of wine.

Rectification is a second process of distillation, the object of which is to purify a liquid substance. In it, heat is employed to carry off the purest and most volatile part, leaving the more fixed matter, which debased

it, in a separate state; as is done, for instance, with spirit of wine, æther, &c.

Concentration is the direct contrary of rectification; its object being to volatilize part of the water, and thus improve the strength of the fluids concentrated. The matter to be concentrated must therefore be of superior gravity to water. This operation is performed on some acids, particularly on the sulphuric and the phosphoric; it is also employed on solutions of alkalis and neutral salts.

Digestion is the exposing of substances which we wish to act gently on one another to a gentle and long continued heat. It is chiefly used to extract those parts of vegetable substances which are soluble in spirit of wine or other fluids. Chemists formerly put great confidence in this operation. Though that confidence seems to have been justly due, as it appears from many painful researches, that too active or too rapid a fire alters the nature of most vegetable and animal substances; yet modern chemists do not depend on this process with the same enthusiasm as the alchemists of old. The patient industry of these people was often employed for a series of years on one process of digestion; for by such processes they expected to perform wonders. Digestion is now confined to dyeing stuffs, elixirs, and liquors for the table; it is always successfully employed to extract the principles of vegetables and animal matters, without altering them. It is likewise useful in several operations on minerals.

Infusion is a well-known process: it consists in pouring warm or boiling water on substances of which we wish to extract the most soluble parts, and of which the contexture is so slight as to be easily penetrable, such as thin bark, wood in small thin pieces, leaves, flowers, &c. It is of great use for separating substances

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that are easily soluble, and is often employed in chemical operations.

Decoction; or the continued ebullition of water with such substances as are liable to be affected by its impression, is used to separate those parts of bodies which are not soluble by a more moderate degree of heat. It produces considerable alterations on vegetable and animal matters; often effecting an entire change of their properties. It coagulates the lymph, melts grease and rosin, and hardens the fibrous parts of a vegetable or animal. When the chemist is well acquainted with its effects, he may employ it with considerable advantage.

In the process of lixiviation, we dissolve, by means of warm water, the saline and soluble particles of cinders, the residues of distillation and combustion, coals, and such natural earths as we wish to analyse. This operation very naturally derives its name from the *lixivial* salts which are obtained by means of it. The word *lessive* is at present used in France as synonymous with *lixiviation*, and is even more frequently used. This operation, then, is merely a solution effected by means of heat: it is likewise nearly similar to infusion; the only difference is, that the latter is applied to vegetable and animal matters; while lixiviation is only employed to obtain substances possessing some of the properties of minerals.

These are all the operations in chemistry in which fire is called in to act a part. Formerly, indeed, no chemical operation was performed without the help of this agent; and the science was on that account named *Pyrotechny*. But as methods of analysing bodies have been since discovered which are much less liable to error and more certain in their results; the agency of

fire is now much less used in chemistry than formerly. The action of solvents, or menstrua, employed in a cold state, or in the ordinary temperature of the atmosphere, is often sufficient to accomplish the most surprising changes on natural bodies, and affords ground for the most accurate inductions. This method has been applied to the examination of salts, earths, and vegetable matters, &c. with the happiest success. Heat is no more than a secondary mean, a kind of auxiliary that affords some assistance on such occasions. As different degrees of heat are requisite in different operations, it would be an happy circumstance if some means were contrived, by which we might be enabled to apply always the same precise degrees of heat when the same effects were wanted. Chemists and philosophers have long wished for a furnace which might afford regular and uniform degrees of heat: Hitherto, however, the manipulations of artists have given the only means that can in any degree serve that purpose. But perhaps it is not impossible to obtain that precision which we desire, and of which the utility is so obvious. Dr Black is said to have invented a kind of furnace, by which he can command a regular and uniform heat by means of a damping-plate with holes, which may be opened or shut at pleasure *. We have not received a sufficiently accurate description of it, to enable us to construct any on the same model. But we hope that a discovery so beneficial to chemistry will not be long unknown in France.

C H A P.

* For a good drawing, and an accurate description of the furnace here alluded to, see the *Edinburgh New Dispensatory*, p. 82^d second edition.

C H A.P. VI.

Of Atmospheric Air.

COMMON air is an invisible, inodorous, insipid fluid, possessed of gravity and elasticity, extremely susceptible of motion, and capable also of refraction and condensation, which encompasses our globe to a certain height, and composes the atmosphere. It likewise insinuates itself into, and occupies, the interstices or pores between the integrant parts of bodies. The atmosphere which encircles our globe is far from being pure air. As it receives all the vapours that arise from the surface of the earth, it may be considered as a kind of chaos, or heterogeneous mixture. We shall by and bye see, however, that its nature is at present pretty well known. Water, mineral exhalations, and elastic fluids disengaged from minerals and metals, are incessantly carried up into the atmosphere, and may be said to constitute its elements. The objects of attention in a natural history of the atmosphere are, its height, the precise degree of which is not yet accurately determined; the variations to which it is liable; its gravity; its different strata; the effects of its rarefac-

tion and dilatation; winds, and meteors. But these come under that part of physics which is known by the name of *meteorology*, and form no part of the province in which we are engaged. Yet as air has a powerful influence on chemical phenomena, and it is of considerable importance to know the nature and extent of that influence, we shall here examine both the physical and the chemical properties of air.

§ I. *Of the Physical Properties of Common Air.*

FLUIDITY, invisibility, insipidity, gravity, elasticity, and negation of smell, may be considered as the physical properties of air. Each of them merits a particular examination.

Such is the rarity of this fluid, that it readily yields to the slightest impulse, changing its situation on the least motion of bodies immersed in it. This kind of fluidity depends on the degree of its aggregative force; and as it is not confined to atmospheric air, but is found to characterise several other fluids, these are called *aeriform fluids*, or *gases*. What constitutes the peculiar nature of aerial aggregation, is incapacity to pass into a fluid state; contrary to what most liquid bodies are susceptible of. By this, however, no more is to be understood, than that hitherto we have not been able to apply to it any degree of pressure or cold sufficient to accomplish this effect. This is the distinguishing characteristic of permanent gases. The fluidity of the air exposes it to those frequent and rapid motions which constitute the winds. It is not, however, capable of penetrating

trating into all bodies. Transparent matters, through which light readily makes its way, are secure against the impulse of air. Water, solutions of salts, oils, and spirit of wine, pass through many bodies whose texture is such as not to admit air. These liquid substances are endowed with the property of dilating such bodies, enlarging their pores, and diminishing the closeness of their texture; of which air is destitute.

Air, when confined in vessels, is absolutely invisible, not to be distinguished from the glass that contains it: even when entirely filled with this substance, phials present to the eye a seeming vacuum. It owes this property of invisibility to its tenuity and the ready passage which it affords to the rays of light: these are refracted, without being reflected by it. And it is therefore destitute of colour; though some natural philosophers have persuaded themselves that they discovered large columns of it to be blue.

Naturalists have uniformly considered air as an insipid body. Yet, in attending to what happens, when the nerves of animals are exposed to the contact of this fluid, as in the instance of wounds, and on other similar occasions, we cannot but observe that it has a kind of pungency; of which we are not generally sensible, only because we are so constantly accustomed to it. Wounds, when uncovered and exposed to the air, are affected with an acute pain. A new-born infant expresses by its cries the disagreeable sensations which it feels from the first contact of the external air. This pungency of the air is to be considered as the reason why wounds that are exposed to it, uncovered, remain so long open. Atmospheric air, in the same manner, impedes the growth of new bark on such vegetables as have been stripped of their covering. In order that

trees may regain their bark, they must be covered over with some body which may exclude the air.

Air is perfectly inodorous. If the atmosphere sometimes affects our organs with a kind of fetid smell, that is to be attributed to the extraneous bodies that are mixed with it; as may be observed in mists and vapours.

The gravity of air is one of the finest discoveries of natural philosophy: the fact was never certainly known till about the middle of the last century; tho' Aristotle indeed is said to have known that a bladder was heavier when filled with air than when empty. The ancients had no distinct idea of the gravity of air, but ascribed to a certain occult quality, which they called *abhorrence of a vacuum*, all those phænomena which depend on the weight of this body. Certain workmen finding it impossible to raise water by a pump above the height of two and thirty feet, were induced to consult the famous Galilæo on the occasion. He was amazed at the phænomenon. Death prevented him from discovering the reason of it; but this was afterwards discovered by his disciple Torricelli in the following manner. He reflected, that water could not rise in a sucking pump, without being impelled by some exterior cause, the pressure of which forced it to follow the motion of the piston. The influence of that cause must be limited, since it never raised the water above the height of two and thirty feet. Therefore, if it were to act upon a body of greater specific gravity than water, it would raise that body only to a height proportioned to its gravity. He next took a glass tube six and thirty inches in length, and hermetically sealed at one end: this he filled with mercury, holding the close end down, and stopping the upper end with his finger,

finger, after he had poured in the mercury: then, turning the close end up, he immersed the other into a vessel full of mercury; and upon removing his finger, found that part of the mercury in the tube had fallen down into the vessel, but that a considerable quantity still remained; which after various oscillatory motions, at length settled at 28 inches. By comparing this with the height of 32 feet, to which water rose in the pumps, he perceived that the difference of the elevations to which these two fluids rose was in exact proportion to the difference between their specific gravities; for the proportion of the specific weight of mercury to that of water is as 14 to 1, and the water rose 14 times as high as the mercury. It was not, however, till after long reflection, that he began to conjecture the weight of the air to be the cause why fluids were thus suspended in a pump. Nor was the existence of this weight certainly determined, till after the ingenious experiment which Pascal directed to be made in France.

That celebrated philosopher imagined, that if it were actually the weight of the air which caused water to rise to the height of 32 feet in a pump, and mercury to the height of 28 inches in Torricelli's tube, these fluids would rise to different elevations on the summit of a mountain and in a vale; as in the former case the weight of the atmosphere must be diminished. In consequence of this suggestion of Pascal's, Perrier made the famous experiment which finally determined the opinions of philosophers concerning this phenomenon, on the 19th September 1648, at the foot and on the summit of the mountain Puits de Dome, in Auvergne. The barometer, or Torricellian tube, being filled with mercury, and fixed to a scale of 34 inches, divided into inches and lines, the mercury rose
about

about four inches higher at the foot of the mountain than on its summit, which is 500 toises higher. From this it was determined that the mercury varied about an inch for every hundred fathoms: and the barometer has since that time been very successfully applied to the measurement of the height of mountains.

The weight of the air has an influence on many physical and chemical phenomena. It compresses all bodies, and resists their dilatation; it opposes the evaporation and volatilization of fluids: and to it the waters of the sea owe their liquidity; for they would otherwise be reduced to vapour, as may be observed of fluids placed in the vacuum produced by the air-pump. Air, by its gravitation on our bodies, retains both the solids and fluids in their proper places: and the blood often bursts through the skin, or from the lungs, on the tops of mountains, occasioning hemorrhagies; because the gravity and pressure of the air are there considerably diminished.

Lastly, air possesses great elasticity. However strongly compressed, it instantly returns to its former rarity as soon as the compressing cause ceases to act upon it. The truth of this assertion is proved by a great many experiments. We shall here mention only the most obvious and most conclusive of those physical facts by which it is evinced. Take a tube of glass, bent into a form somewhat like the letter U, and close at one end; fill it nearly up with air, and then pour in a quantity of mercury to prevent the air from escaping: you may thus compress the air so as to know what degree of compression this elastic fluid is susceptible of, by comparing the diminution of its bulk with the height of the column of mercury employed to compress it. A foot-ball, which being filled with air rebounds from
any

any hard body, affords another proof of the elasticity of this substance. The fountain by compressed air, gives an instance of the same fact: Air being compressed into the superior part of this vessel, is soon dilated by the heat of the atmosphere, so as to force the water out by a tube to a considerable height. Lastly, the wind-gun, the effects of which are generally known, is another instrument for showing the elasticity of air, and the compression of which it is susceptible. It is computed, that air may be compressed into $\frac{1}{11}$ th of its ordinary bulk.

Heat, which rarefies it by counteracting any compressive force to which it is exposed, shows that it is no less capable of enlarging its bulk by dilatation. If a bladder full of air be exposed to the heat of a furnace, the air will be dilated so as to burst the bladder with a violent explosion. This is likewise often the cause of the bursting of the vessels in chemical operations; against which, however, proper precautions are now adopted. The diminution or total abstraction of the weight of the atmosphere, which is effected by the air-pump, affects a bladder filled with air in the same manner as a violent heat.

The reader will naturally conclude from this account of the gravity and elasticity of air, that many of the variations which we observe in the atmosphere and on the barometer are owing to these properties. In fact, the inferior support the superior strata of the atmosphere; and the compression of a stratum of air is always less or greater in proportion as it occupies an higher or lower situation. Heat also, which is constantly varying, has the power of modifying this gravity and elasticity. These are the reasons why air is found to be lighter, keener, and more agitated, &c.
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on the tops of mountains, than on plains and other less elevated situations. To understand those astonishing phenomena which the barometer offers to our attention, we must study the gravity and elasticity of the atmosphere, as well as the changes to which it is liable, from the influence of heat. M. de Luc and M. Saussure, have for some years paid much attention to this class of the phenomena of nature.

§ II. *Of the Chemical Properties of Common Air.*

THE properties above described are all that were anciently considered by philosophers as belonging to air. Several chemists, at the head of whom Van Helmont, Boyle, and Hales, deserve to be ranked, observing that air, or at least a fluid with all the apparent properties of air, was obtained in the analysis of many natural bodies, inferred, that this element subsisted in those bodies in a combined and fixed state. Hence arose the name *fixed air*, which was at first given indifferently to all the elastic fluids obtained in chemical operations. The above mentioned philosophers supposed these substances to be of the same nature with atmospheric air: But Dr Priestley has discovered a number of elastic fluids, which, though apparently the same with common air, yet differ from it in many respects. We must then have recourse to other qualities, if we wish to distinguish atmospheric air from the other aeriform fluids, which like it are invisible and elastic. Its chemical properties afford the

only

only criterion on which we can establish this distinction.

In examining the distinctive properties of air, we find two which are peculiar to it, and may very well serve to mark its character: one, its being favourable to combustion or inflammation; the other, its serving to maintain animal life in respiration. Let us carefully examine these two great phænomena.

It is exceedingly difficult to give a good definition of combustion. It is not one, but a number of phænomena which combustible bodies offer to our observation, when they are heated and exposed to the action of the air. The chief of them are heat, motion, flame, redness, and the change of the nature of the substance that is burnt. There are many varieties among combustible bodies. Some of them burn briskly, and afford a brilliant flame, such as oils, wood, resinous and bituminous substances, &c.: others burn away without producing a discernible flame; as for instance many of the metals, and charcoal which has been properly prepared: others again are consumed by a slow motion, scarce observable, almost without seeming to be on fire, but always with a degree of heat;—such is the combustion of some metallic matters. Combustion, however, takes place equally in all these instances; and the body which has been once burnt in any of these ways is no longer susceptible of inflammation. The residue is always heavier than the combustible body. This may be easily proved to be the case with fixed combustible bodies. But again, those of which the inflammable matter is of a volatile nature, burn with more rapidity than the former, and their fixed residue wants much of the original weight. From this it may perhaps be thought, that these last lose much of their weight

weight in burning: but it is only a seeming loss they suffer; and there are no combustible bodies of which the residues are not weightier than before combustion. For what remains fixed on such occasions is not the only residue of the combustible body; a considerable part of volatile combustible bodies is converted into elastic fluids, which ascend and are diffused through the atmosphere: and were we to suppose that these leave no other residue but what appears after their combustion on the spot, or in the vessel where they were burnt, we must believe what is impossible, that they afford no residue. *Æther* and spirit of wine burn away without leaving the smallest particle; but the substance into which they are converted is volatilized and diffused through the atmosphere. When means are employed to collect it, it is found to possess more gravity than the combustible body from which it was produced. Thus, by burning sixteen ounces of highly rectified spirit of wine under a chimney adapted to the worm-pipe of a still, M. Lavoisier obtained eighteen ounces of water as the product of that combustion. Oils, resins, &c. present the same phenomenon. Thus, the cinders of burnt wood are not the whole of the residue which it affords; the rest ascends in the air: one part, not being thoroughly burnt, becomes soot; and the other mixing with the atmosphere, is condensed into water, or deposits in it some other elastic fluids. It is therefore an established truth in chemistry, that all combustible bodies acquire additional weight by being burnt.

To understand how this addition of weight is acquired, we must attend to another of the phenomena of combustion, which it will be necessary to explain more at large. Combustion can never take place without

the help of air, and is always in proportion to the purity and the quantity of that fluid. Ever since the discoveries of Boyle and Hales, philosophers have been struck with this fact, and have proposed a variety of hypotheses to explain it. Boerhaave thought that air contributed to combustion by operating on the surfaces of combustible bodies, so as to dissect them, if the expression may be allowed, into their component particles. This hypothesis did not explain why the same air could not always promote combustion. M. Morveau supposed this last fact to depend on the extraordinary rarefaction of the air by heat; in consequence of which, it acquired such elasticity as to prevent the combustion of inflamed bodies by forcible compression. But he offered this ingenious hypothesis at a time when it was impossible to distinguish the true cause of the phenomenon. M. Lavoisier, by a series of fine experiments on the calcination of metals with determinate quantities of air, has proved, that, as John Ray the naturalist had before observed, so much air is absorbed during calcination, that the calcined metal acquires precisely that quantity of weight which the air loses during this process; and that the portion of air absorbed actually remains in the metallic calx, as the calces of mercury may be reduced merely by expelling that fluid. Other facts led him still farther. He observed, with Priestley, that the air which remains after the process of calcination or combustion, can no longer serve to promote new processes of the same kind; that it extinguishes flame, suffocates animals, and, in a word, has acquired a different nature. He likewise found that its diminution is exactly proportioned to the quantity absorbed by the combustible body. On the other hand, air extracted from metallic calces has been

been found three or four times purer than atmospheric air. It not only promotes combustion, but even renders it much more rapid. A given quantity of the former will serve for the inflammation and total combustion of three or four times that quantity of matter which may be consumed by the help of the same portion of the latter. To this singular fluid obtained from the calces of mercury, Dr Priestley, who first discovered it, gave the name of *dephlogisticated air*; because he considered it as atmospheric air deprived of the phlogiston, which, according to him, is diffused through the whole atmosphere. Its phlogiston he believed to be retained by the mercurial calces, which are gradually reduced as this elastic fluid is disengaged by heat. But as that name may lead to a false idea of its nature, we will give it the name of *vital air*; for it alone is the great agent in respiration, as well as combustion; and to use the expression of M. Lavoisier, it has four times as much of the genuine nature of air as common air has.

From thus observing that air is absolutely necessary to combustion, and that part of the air necessary to the calcination of metals remains in the calces, M. Lavoisier was at first led to think, that combustion consisted in the absorption of pure air by the combustible body. Abstracting the water and vapours contained in atmospheric air, he considered the substance that remained as a compound of two very different elastic fluids. One of these, which is the only genuine air, and which promotes combustion by precipitating itself into the combustible body, and uniting with it, is vital air. It generally composes a fourth part of the atmosphere, and sometimes even a third part, when it is in its purest state. The other fluid is deleterious to animals, and
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extinguishes flame; and it constitutes three-fourths or two-thirds of the atmosphere: it was at first named mephitic air. When a combustible body is exposed to the air and kindled, a portion of the vital air in the atmosphere becomes fixed in that body, and its combustion continues till it absorb all the vital air immediately around it. The residue of the air, after it has lost this pure vital part, can no longer contribute to combustion. It regains this power on being again qualified with a due quantity of pure air extracted from nitre or a metallic calx. This elegant theory proposed by M. Lavoisier in the years 1776 and 1777, appeared to explain all the phænomena of combustion. It accounted for the additional weight acquired by metallic calces, and the extinction of flame by air that has been already employed in combustion. But M. Lavoisier, after continuing his experiments on the subject, has thought proper to modify and enlarge it by new observations. The bright flame which is observed on immersing a burning body in vital air, or on pouring that fluid on the surface of a flaming substance (which may be done by means of an ingenious machine of his invention) made him desirous of knowing whence it proceeded, and whether, according to the theory of Stahl, it were owing to the disengagement of phlogiston. He inquired into this with the more attention, because the celebrated Macquer had still persisted, notwithstanding *his* discoveries, in maintaining Stahl's theory, but had laboured to reconcile *his* theory with that of the father of philosophical chemistry. Macquer was of opinion, that pure air became fixed in combustible bodies in consequence of their phlogiston being disengaged; and that pure air and phlogiston were reciprocally precipitated; the one from the atmosphere

into the combustible body, the other from that body into the atmosphere: in every process of combustion pure air extricated phlogiston into a state of liberty, and assumed its place; and in the reduction of metals, phlogiston disengaged pure air and occupied the room which it had formerly possessed. M. Lavoisier observing that the bright sparkling flame before mentioned, which affords the strongest indication of the presence of light or the matter of fire in a state of activity, seems rather to surround the exterior part of the body in combustion, than to proceed as if it were disengaged from it,—has been led to think that light and heat are separated from vital air, in proportion as it is absorbed by the body in combustion. His present opinion is, that vital air, like all other aeriform fluids, is a compound, consisting of a certain principle susceptible of solidity, and of fire or the matter of heat; that to its possessing the latter it owes its state of elastic fluidity; and that, being decomposed in combustion, its fixed, solid principle, by entering into combination with the combustible body, increases its weight and changes its nature,—while the matter of fire that it contains is disengaged under the form of light and heat. Thus, the modern doctrine has bestowed on vital air what Stahl attributed to phlogiston. If combustion consist in the disengagement of fire, it is air, not the combustible body, which burns. As to the principle which, in combination with the matter of fire, constitutes pure or vital air, though M. Lavoisier is not yet perfectly acquainted with its nature, yet as it is often known to form acids by entering into combination with combustible substances, he has conferred on it the

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name of the *oxigenous* principle *. With this base, the sulphuric, arsenic, and phosphoric acids, &c. are produced in the combustion of sulphur, arsenic, and phosphorus, &c. In all these bodies it is still the same. It is to be observed, that according to this new theory, the vital air which is obtained from metallic calces did not exist in these calces under that form. It becomes such, in consequence of the combination that takes place between the heat and light communicated through the vessels in which the calces are contained during this process, and the oxigenous principle by which they are constituted calces.

Such is the present state of chemical doctrine (May 1787) concerning the nature of atmospheric air, and its influence on combustion. The theory of which we have given an account is daily gaining new strength. The objections urged against it have but little weight: they even show, that if its opposers were better acquainted with it, they would cease to raise their voice against it, and that when it becomes generally known, it will be unanimously received by the learned.

Respiration is a phenomenon nearly resembling combustion. Common air is decomposed in the one as well as in the other; that it may contribute to either, it must contain a certain quantity of vital air. When it is deprived of all its vital air, the mephitic residue is fatal to animal life. Respiration is in fact but a slower combustion, in which part of the heat of vital air enters the blood as it passes through

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* M. Lavoisier gave it at first the name of *oxigyne*; but finding it necessary to apply an analogous name to some other substances, before known by improper denominations, we have changed the *gyne* into *gene*, as more expressive of its Greek derivation.

the lungs, and is by it conveyed through the whole body. In this manner animal bodies receive their supplies of heat, which are absolutely necessary, as they are constantly giving out the heat which they contain to the atmosphere and other surrounding bodies. To maintain the heat of the blood is, therefore, one of the chief purposes of respiration; and this beautiful theory explains why the blood of those animals that respire either no air or but very little, is always cold.

Messrs Lavoisier and de la Place have discovered another service which the air performs in the act of respiration. It absorbs a certain principle that exhales from the blood, and appears to be of the same nature with coal. That substance being reduced into vapour enters into combination with the oxygenous part of vital air, and forms the carbonic acid which is discharged from the lungs by expiration. This fact,—the formation of the carbonic acid in the atmospheric air respired by animals, at the same time when the *mephitic* air is separated,—explains why such dangerous effects ensue from the shutting up of a number of persons together in close places; such as happens in theatres, hospitals, prisons, and the hold of a ship, &c. After this, we can no longer be surprised at the noxious effects of air altered by respiration, by which persons of delicate constitutions and great sensibility of nerves are particularly liable to be affected.

The atmosphere which encompasses our globe appears, therefore, to be suffering continual alterations from the two great phenomena of combustion and respiration. That fluid would be very inadequate to these two great purposes, were there not other means provided for renovating the atmosphere, and maintaining it with constant supplies of vital air. In the following

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Following chapter, and in the third part, we shall see that the organs of vegetables are designed by nature to extract this vital air from water, as well as to pour it into the atmosphere, when struck by the rays of the sun.

§ III. *Of the distinguishing Properties of that Mephitic Air, or Azotic Gas, which enters into the Composition of Atmospheric Air.*

FROM the preceding account of atmospheric air, it appears to be a compound body, consisting of two gases or elastic fluids; one of which maintains combustion or respiration, but the other is entirely unfit for either of these purposes. The first, which is named vital air, exists in the proportion of 0,27 or 0,28; while the latter amounts to 0,73 or 0,72. We have asserted the first to be a compound of the caloric and the oxygenous principles; the second, like all other gaseous bodies, is also a compound of the caloric principle with a base susceptible of solidity. To this elastic fluid, which constitutes more than two thirds of the atmosphere, M. Lavoisier at first gave the name of *mofetic* air; because it extinguishes combustion, and destroys animals. But since all gases, except vital and atmospheric air, are equally noxious, and are therefore all equally intitled to the name of *mofettes* or *mephites*, which has been always applied to elastic fluids unfit for respiration;—we have adopted the word *azotic gas* as the peculiar denomination of *this* aeriform fluid: and we may of consequence apply the substantive *azote*,

or the term azotic principle, to the base of this gas; which, like the oxygenous principle, the base of vital air, becomes fixed by entering into combination with a number of substances. In order to give some idea of the nature of this azotic gas, we shall mention a few of its properties. It is somewhat lighter than common air, and therefore occupies the upper part of rooms in which the air hath been altered by combustion or respiration. Though so noxious to animals in the state of elastic fluidity, yet the azotic principle, its base, is one of the component principles of animal bodies; from which it is extracted in great abundance. It is likewise one of the constituent parts of volatile alkali or ammoniac, and of the nitric acid. It appears to be absorbed by vegetables, and perhaps also by animals. It is highly probable that the same principle enters into the composition of all alkaline bodies, and may be considered as a genuine *alkaligenous* principle, in opposition to the base of vital air, to which we have given the name of the *oxygenous* principle. Thus we are led to consider the atmosphere as a vast reservoir of *acidifying and alkalifying* principles, though it be itself neither acid nor alkaline.

Here we can only mention these properties; in the succeeding part of the work they shall be more particularly explained. Here we have only endeavoured to point out the difference between the two fluids of which our atmosphere consists, and to fix the reader's attention on the nature of each as distinct from the other.

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C H A P. VII.

Of Water.

WATER was long thought to perform an important part in almost all the phænomena of nature, and to be capable of assuming a vast variety of forms, and entering into many combinations, without suffering any alteration of nature, or becoming unable to resume its original state. But the late researches of Messrs Lavoisier, Meunier, de la Place, and Monge, have discovered that water, like air, is compounded of more simple principles which may be obtained separate. The period of this important discovery constitutes a glorious æra in the history of chemistry. We shall afterwards see by what means these philosophers accomplished the analysis of water. Let us first consider the chemical properties of this body.

§ I. *Of the Physical Properties of Water.*

PHILOSOPHERS define water to be an insipid, ponderous, and transparent fluid, without colour or elasticity, extremely susceptible of motion, and capable of passing through the various states of aggregation, from the solidity of ice to the tenuity of vapour or elastic fluidity.

It is found in almost all natural bodies; but nature has united it with many substances with which art has not yet learned to make it enter into combination. It is obtained from wood, and from the most solid bones; it is known to exist in the hardest and most dense calcareous stones; it constitutes the most considerable part of animal and vegetable fluids, and even enters into the composition of the solid parts of such bodies. These are the facts which gained it a place among the number of the elements.

The natural philosopher views it as existing in masses over the globe, filling up its cavities, or channelling its surface. Its history comprehends that of the eternal ice which covers the summits of some lofty mountains and the polar seas, of lakes, rivers, rivulets, springs, clouds, rain, hail, and snow. It is distinguished into terrestrial, and atmospheric water. It attracts the curious inquiry of the philosopher, in its passing successively from the surface of the earth into the atmosphere, and from the atmosphere upon the rising heads of hills; and again, in its gathering into streams, producing springs, fountains, and rivers; and in the last form, holding

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holding its headlong course to its great reservoir the sea. Observing the phenomena of this immense mass of water, we behold it agitated with the most tremendous motions; we see its fluctuations and currents sometimes raising awful liquid mountains; we see it sometimes encroaching on the limits of the earth, and sometimes retiring within its ancient boundaries. Here new islands spring up from its depths; there the foundations of isles of ancient name are lapped, and they swallowed up in its bowels. If we trace its action in subterraneous cavities, we there find it engaged in humbler labours, producing salts and crystals, and depositing them in the clefts of the rocks. All these objects must come under our attention in pursuing the natural history of water. But we must first examine its physical and chemical properties.

The most remarkable of these is its being susceptible of various forms, and becoming by turns a solid, a liquid, or a vaporous body. Let us consider it under each of these three modifications.

I. Of Water in the State of Ice.

Ice seems to be the natural state of water; for, in chemistry at least, we consider that as the natural state of any body in which its aggregative force is strongest: But as it appears much more frequently in a liquid state, liquidity is still considered as the natural state of water.

Several phenomena highly worthy of observation occur in the formation of ice.

1. The change of a liquid into a solid body, which takes place on the freezing of water, occasions a heat
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of some degrees. In a thermometer immersed into freezing water, the mercury rises some degrees above 32° ; while in another, in the open atmosphere of the same temperature, it either remains fixed at that point or sinks below it. It appears, therefore, that part of the heat which is fixed in water in a liquid state, is disengaged and escapes into the atmosphere when it assumes a solid form; and the specific heat of ice is actually less than that of water. A similar disengagement of heat is observed in the crystallization of salts.

2. The external air promotes the formation of ice. Water in a close vessel freezes but very slowly; but expose it to the open air, even in the same temperature, and ice will almost instantly appear. A similar phenomenon is observed in the crystallization of salts: many saline solutions, which in close vessels are maintained in that state, will almost in an instant display crystals, if you open the mouth of the vessels and expose them to the contact of the atmosphere.

3. Gentle motion is favourable to the production of ice. The same thing is observable of saline crystallizations. By shaking some solutions, which otherwise would not produce crystals, we sometimes see these appear while the shaking is continued. I have often observed this in solutions of calcareous nitrate and muriate. These analogies between the formation of ice and that of saline crystals prove, that the former is actually a species of crystallization.

4. The bulk of a piece of ice appears to be greater than that of the water of which it is formed; bottles and other glass vessels are burst in consequence of the freezing of liquids with which they are filled. But this effect is to be ascribed not to the water, but to

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the air which is disengaged from it during its congelation.

When ice is formed, it is distinguished by the following properties.

1. It has been observed by M. Mairan, that when formed by a slow congelation, its crystals are in the form of needles crossing each other at angles of — from 60° to 120° . Sometimes its crystallization takes a regular and determinate form. M. Pelletiers, a scholar of M. D'Arcet's, and member of the college of pharmacy, observed in a piece of fistulous ice crystals in the form of flat quadrangular prisms, terminating in two dihedral summits, but with great varieties. On the other hand, when ice is suddenly formed, and in large masses, it becomes one irregular solid, exactly like that produced when solutions of salts are pressed close together and suddenly cooled.

2. Its solidity is so great, that it may be reduced to powder, and carried about by the wind. In very cold climates, ice becomes so hard that it may be hewn into pieces like stone, and used in building. Nay, we are even confidently told, that masses of ice have been hollowed into cannons, and charged and discharged several times before melting.

3. Its elasticity is very great, much greater than that of water in a fluid state. Throw a piece of ice on a solid plane, it rebounds from it like any other hard body.

4. It has a keen, sharp taste, nearly approaching to causticity. Every person knows what kind of sensation ice gives when applied to the skin. Physicians employ it in external applications as a tonic or discutient, &c.

5. Its gravity is less than that of the fluid on which
it

it swims; which seems to be occasioned by its containing a greater quantity of air in proportion to its bulk. The same phænomenon takes place on most of those bodies that admit of concretion by cold, and fusion by heat, such as butter, fats, wax, &c. and still arises from the same cause; for every substance is by itself more dense and weighty in its solid than in a fluid state.

6. Its transparency, at least in irregular masses, is obscured by air-bubbles. You may be convinced of this by examining a piece of ice attentively; and if the cavities be opened under water, the air which they contain will be seen to issue in bubbles from its surface.

7. It melts at some degrees above 32° ; the liquefaction proceeding gradually from the surface to the centre.

8. Passing from a solid to a liquid state, it produces cold in the surrounding atmosphere. Modern chemists think that it absorbs heat when it melts; and that the quantity of the caloric principle which becomes fixed in it on that occasion, is equal to the quantity of heat disengaged when it passes from fluidity into the state of ice. The same phænomenon is common to all fluid bodies that can be condensed into solids, and again reduced to fluidity by the variation of their temperature.

II. *Of Water in a Fluid State.*

THE properties of water in a fluid state are very different from those of ice.

I. Its taste is much fainter, for it is generally considered

dered as insipid. And yet people that drink much of it, can distinguish differences in its taste at different times, &c. ; which shows that it is not absolutely insipid.

2. Its elasticity is less than that of ice. Some experiments of the Academy *del Cimento*, have even caused this property to be entirely denied to it. But the Abbé Mongez has proved the elasticity of water by a series of ingenious researches ; and has even shown, that the experiments of the Academy admit of an inference directly opposite to that which has been deduced from them. For the metal spheres, which had been filled with water for those experiments, continued to exude liquid drops after being taken out of the press ; which could not have happened if the water had suffered no compression.

3. In the state of a liquid aggregate, water is more under the influence of the affinity of composition. From this circumstance it has obtained the name of the great solvent of nature. It does indeed enter into union with a great many bodies, and even contributes highly to the mutual combination of bodies.

4. It seems incapable of combination with light, which passes through it without producing or suffering any alteration. Light is known to change its course in passing through water, so as to assume a more perpendicular direction.

5. Heat dilates it to a gaseous state. Its passing from a liquid state to that of aeriform fluidity constitutes ebullition. The cause of this phenomenon is, that, part of the mass of water under examination having assumed the form of an elastic fluid, the heat no longer suffers it to remain in union with that which is still liquid : each bubble rises from the bottom of the vessel,

vessel, and ascends into the atmosphere, in obedience to the action of heat. I have explained the cause of ebullition at large in my *Memoires de Chimie*, published in 1784, page 334.

The weight of the air has a remarkable influence on the ebullition of water. It opposes its dilatation and evaporation: And in proportion as the gravity of the air is less or more, the resistance which it opposes to the volatilization of water must be weaker or more powerful. Thus, Fahrenheit observed, that the temperature of water in a state of ebullition is not always the same. In order then, to know with greater certainty the precise degree of heat at which water boils, we must consult the barometer as well as the thermometer, and we shall find the requisite heat always proportioned to the weight of the air.

The influence of the weight of the air on the rarefaction and ebullition of water becomes more remarkable when we make our observations at various heights in the atmosphere. Thus, *ceteris paribus*, water boils easier on the summit of a mountain than in a valley or on a plain; the heat requisite to produce ebullition being less in the former situation than in either of the two latter. All fluids are easily rarefied at very elevated heights; for this reason, liquids that are highly volatile, such as spirit of wine, æther, and alkaline or ammoniac gas lose much of their strength on the tops of mountains; a fact which has been generally observed by natural philosophers, and fully determined by an observation made by M. de Lamanon, at the height of more than 1800 toises above the level of the sea. Abstract the weight of the atmosphere with the pneumatic engine, and you may heat water to ebullition, and

and reduce it to vapour, without raising it to the temperature of 40° .

Lastly, A third circumstance, besides the heat and the gravity of the atmosphere, which affects the ebullition of water, is the dryness or humidity of the atmosphere; but as the influence of this circumstance is entirely chemical, we shall reserve the consideration of it to the next section.

6. Boil water in a close vessel, and with a suitable apparatus for collecting the vapours; let these be condensed by cold, and conducted into a receiver; what is thus obtained is distilled water. By this means water is obtained pure, and separated from those earthy and saline matters which almost always alter it, but are now left in the bottom of the vessel. Chemists, who always need pure water for their experiments, provide themselves with it in this way. They pour river or fountain water into a cucurbite of copper tinned over within: this they cover with a capital inserted into a refrigeratory filled with very cold water, for the purpose of condensing the vapours; which are thus caused to pass in drops into glass-vessels prepared for their reception. But in order to obtain distilled water in the greatest purity, an alembic peculiarly adapted for this purpose must be employed. To abridge the process of distillation, this vessel should be prepared on particular principles; the cucurbite should be broad and flat, and the capital of the same form. Water thus distilled is perfectly pure. Chemists formerly made use of snow or rain water; but these are now known to contain solutions of some extraneous substances.

Distilled water has an insipid taste, and when drunk oppresses the stomach with a kind of weight; but after being exposed to the open air, and briskly shaken, it
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recovers its taste, and may be drunk with safety. Distillation does not alter water, it only deprives it of the air which is always united with it in its ordinary state, and communicates to it that lively fresh taste which renders it potable. Boerhaave distilled a quantity of water 500 times successively, without being able to discover any alteration upon it. Some philosophers have at different times asserted, that water is changed into earth; because, at each new distillation, it leaves a certain quantity of an earthy residue in the bottom of the vessel. M. Lavoisier has made a series of most accurate experiments, with a view to determine this. By weighing the glass vessels employed in the process of distillation, and doing the same with the water distilled and its residue, he has discovered that this earth is nothing but a part of the matter of the vessels ground down by the action of the water.

III. *Of Water as an Elastic Fluid.*

WHEN water is reduced by the action of fire into the state of vapour or elastic fluidity, it acquires new properties which distinguish it from what it was under the two former modifications.

1. If the air into which it is received be above the temperature of 65° , and not overcharged with humidity, it becomes perfectly invisible.

2. If the temperature of the atmosphere be below 53° , and, if it be already loaded with moisture, the watery vapour forms a white or grey cloud, which is very plainly distinguishable: The reason of this is, that it is not dissolved in humid air, as shall be afterwards

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wards shown; but a true precipitation actually takes place.

3. Its dilatation is so considerable, that, as M. Wath assures us from the most accurate computation, it occupies, in this form, 800 times the space which it fills when liquid.

4. Such is its elasticity, that when compressed, it produces dreadful explosions; and is happily employed in mechanics to move enormous masses. Its utility in that valuable machine the steam-engine is well known both to philosophers and artisans.

5. Agreeably to one of the most uniform laws of the affinity of composition, it has a greater tendency to combination in this state, in which its aggregative force is weakest, than in the two former. Chemists have frequently occasion to observe with what rapidity water in the state of vapour dissolves salts, softens mucous substances, corrodes and calcines metals, &c.

6. It is entirely dissolved in air; when precipitated from the atmosphere, it constitutes dew. This solution obeys the same laws with saline solutions; as has been shown by M. Le Roy of Montpellier, in an excellent memoir on the elevation and suspension of water in the atmosphere, (*Melanges de Physique et de Medicine, Paris, 1771.*)

7. One of the most remarkable phenomena of water in a vaporous state, is its power of quickening the combustion of oil; as in the experiment of the æolipile applied to the enameller's lamp, in common fires of mineral coal or charcoal, and in the burning of grease; instead of extinguishing, water rather increases the strength and fury of the flame in all these instances. These phenomena led Boerhaave to think that flame was in a great measure composed of water. We will see how much

this ingenious conjecture of Boerhaave's is confirmed, or at least justified by the modern discoveries concerning water, when we come to show that this fluid, in a vaporous state, increases the violence of flame, in consequence of being itself decomposed by the bodies in combustion.

8. Water in vapour, and dissolved in the air, is condensed, and part of it precipitated, when exposed to a temperature a few degrees above the freezing point; it then resumes its liquidity; and in this manner is dew produced. Sometimes, when exposed to a sudden cold several degrees below the freezing point, it is congealed into icicles, and seems to suffer a kind of crystallization: hence those hoar, icy incrustations that are formed in winter on the windows of apartments exposed to the north: hence too those small icy flakes into which the aqueous vapours issuing from the lungs are formed in Siberia and other countries exposed to an extreme cold.

§ III. *Of the Chemical Properties of Water.*

NO other natural body is susceptible of more combinations than water; and it has, on this account, long held the name of the *great solvent of nature*. The waters of the sea, of lakes, of rivers, springs, and fountains, are far from being pure, and are impregnated with almost every other substance, especially with saline matters.

It combines with air in two ways: 1. It absorbs that elastic fluid and retains it without passing from its liquid

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quid state. It even appears that water owes its pleasant fresh taste to the air thus combined with it. The pneumatic engine proves the reality of this combination; when the air above the water is exhausted, that which is mixed with it is gradually disengaged in the form of bubbles. The air contained in water may be obtained by distilling the water in a pneumatological apparatus. When water is boiled, the first bubbles that arise consist of air, and the water, after losing them, has no longer the same lightness or relish. It recovers these properties by being exposed for some time to the open atmosphere, or by being briskly shaken. 2. Air, with a certain degree of heat, dissolves water, and renders it elastic and invisible like itself. The greater its heat, the greater also is its power of maintaining water in a state of solution. Le Roy of Montpellier has examined with minute attention the state of water in the atmosphere. His ingenious experiments show, that the driest hot air, if inclosed in a flask, and cooled to a certain temperature, affords a precipitate of water; that more or less aqueous vapour is necessary to saturate the same quantity of air according to its heat; and that this water is precipitated from the atmosphere through the night, and forms a particular kind of dew. He has even been led to think, from these facts, that the weight of the atmosphere depends upon the quantity it contains of this water, which is always in proportion to its temperature.

Though it is not consistent with the method which we propose to follow, to enter upon the examination of saline matters in this place; yet we must observe, that water, as it possesses in an high degree the property of dissolving them, always contains a certain

quantity of some saline substance. Calcareous salts are most frequently mixed with water, and communicate some disagreeable, and sometimes even noxious, qualities to well and river waters. These are sometimes also found to contain a portion of the carbonic acid, of clay, of iron, and of the extracts of vegetables altered by putrefaction. All such waters are unwholesome; those vitiated with the former mixture are called crude, hard waters: they have an insipid taste, are heavy upon the stomach, and unfavourable to digestion; and being likewise often purgative, the use of them is not without danger. It is, therefore, an object of considerable importance to distinguish the quality of water; to discover whether it be impregnated with any bodies which may communicate to it noxious properties; and to adopt means for purifying it from such a mixture.

Good wholesome water is generally distinguished by the following characteristics. It is very clear and limpid; no extraneous body alters its transparency; it has no kind of smell; it has a lively, fresh, and almost pungent taste; it boils readily, and without losing its transparency; it entirely dissolves soap, in such a manner as to produce an homogeneous fluid, without clouds or lumps; it boils leguminous vegetables without hardening them: if tried by an addition of those liquors that are named *re-agents*, such as alkalis, and solutions of mercury and silver with nitre, it loses neither its purity nor transparency; or at least if it suffers any change of that kind, it is almost imperceptible. Lastly, it passes easily through the stomach and the intestines, and is favourable to digestion. Spring or river water, which filtrates or flows through sand, is in continual motion, and is not polluted with the putrefaction of animal or vegetable substances,—is found to

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possess all these properties : but filth must not be conveyed into it by sewers ; the channel must not be filled up so as to divert or slacken its course ; nor must hemp be steeped, or foul linens washed in it, &c. On the contrary, water which stagnates in subterraneous cavities, which issues from a calcareous or gypseous soil, which has no current, which is overgrown with plants or crawls with insects, which is very shallow, with a soft muddy bottom, consisting of putrid vegetables ; all such water exhibits quite different qualities. Its taste is insipid or even nauseous ; it has the smell of a mouldy or putrid substance ; it is often green or yellowish ; green or brown flakes of matter, the remains of putrefied vegetable substances, are seen swimming in it ; it turns vegetable blues to green ; it becomes dark and muddy when boiled ; forms clouds with soap, and hardens all kinds of pulse ; the re-agents cause it to give precipitates in greater or less abundance ; it oppresses the stomach, remains long upon it, and retards digestion.

Several means are used to correct these bad qualities, which have been adopted entirely from the consideration of its physical and chemical properties.

1. Stagnant waters are put in motion by cutting out for them a sloping channel, exposing them to the action of mills, causing them to rise in spouts through the air, or to tumble down in cascades. By these means the putrid gas and spiritus rector are caused to evaporate, extraneous matters are collected and deposited in the bottom, and a considerable quantity of air is attracted into combination with the water.

2. Marshes and pools are cleansed of all putrefying animal and vegetable substances : and this cannot be

done without agitating their waters at the same time, which is also serviceable.

3. Water is filtrated thro' jars or fountains, the bottoms of which are covered with fine sand and sponges: these need to be renewed from time to time. The bottoms of small rivulets naturally covered with a bed of mud, are also laid with sand and pebbles.

4. The above are means for purifying water by separating from it such heterogeneous matter as may happen to float in it; but they cannot deprive it of any saline substances that exist in it in a state of solution. To separate these from water, it must be boiled, left to settle and cool till it become clear, then filtrated thro' paper or pure sand, and exposed to the air in broad stone vessels. After undergoing this process, it may be drunk with safety. Ebullition frees hard water of the principle which occasions its disagreeable smell, and causes it to precipitate part of its calcareous salts: but to produce the last effect, the water must be boiled for half an hour, or for so long time as may be necessary to make it dissolve soap, and to deprive it of the property of hardening pulse.

5. If boiling be found insufficient for purifying water of its calcareous salts, as sometimes happens when it is strongly impregnated with them; these must then be precipitated by boiling it with a small quantity of potashes, or for want of potashes with common ashes; the salts then fall to the bottom; and the water being suffered to settle, and exposed to the air, acquires all the qualities which we wish it to possess.

6. We may also make use of some substances to correct the disagreeable and noxious qualities of water, such as sugar, meal, barley, corn, honey, pot herbs, and
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some labiated aromatic plants. But these cannot, like the former means, communicate to it the qualities of pure water; they only substitute one taste in the place of another.

This account of the chemical properties of water represents it only as a powerful agent in combination, capable of entering into union with many natural bodies. But in many of its combinations it suffers a remarkable alteration, which was not taken notice of till within these few years (in the month of April 1784); and which is highly worthy of the attention of chemists. Water has long been known to favour combustion in some instances, as in the enameller's lamp, in the inflammation of oils, in strong conflagrations, &c. Some philosophers had thought themselves authorized by these facts to conclude, that water was sometimes changed into air: but we are indebted to a few French academicians for a more accurate account of these phenomena, and of the nature of water. M. Lavoisier having observed, with M. de la Place, that when inflammable gas is burnt in a close vessel, by the help of vital air, a product of pure water is obtained (a fact which was observed almost at the same time by M. Monge, with the most accurate attention, in the laboratory of the school of Meziere), concluded, that this product must be composed by the combination of vital air with inflammable gas; and that these were the constituent principles of water. This theory, by which M. Lavoisier presumed to deprive water all at once of the character of a simple elementary body, which it had so long maintained, met with keen opposition; and its author found himself under a necessity of establishing it by analytical as well as by synthetical facts. He there-

fore attempted to decompose this fluid, by exhibiting to it bodies, the affinity of which with one of its principles was so strong, that they might be expected to separate it from the other. Obtaining the assistance of M. Meusnier, in his researches on this head, those two philosophers read, in the academy, on the 21st of April 1784, a Memoir, proving that water is not a simple substance, but a genuine compound of the base of inflammable gas with that of vital air or the oxygenous principle; and that the two principles may be easily separated from each other. To obtain these two matters separate, M. Lavoisier at first employed the following process. In a small bell-glass, above so much mercury, he put a certain quantity of very pure distilled water mixed with iron-filings: These filings were gradually calcined; an inflammable elastic fluid was disengaged, and collected immediately above the mercury; and in proportion as these two phenomena appeared, the quantity of the water was diminished. By prosecuting this experiment farther, the iron may be entirely calcined and totally decomposed; for the water, in M. Lavoisier's opinion, both occasions the calcination of the iron and gives out the inflammable gas. As the fluid is composed of the oxygenous principle and the base of inflammable gas, the iron gradually depriving it of the former, combines with that principle to form a metallic oxide, and leaves the inflammable gas disengaged. Such was the first experiment in which this enlightened chemist accomplished the decomposition of water. But in those researches which he prosecuted in conjunction with M. Meusnier, he followed a much shorter and more conclusive process. Placing the barrel of a gun in a fur-

nace, and heating it red-hot, he dropped a certain quantity of water through it. In this process, the water being reduced to vapour is decomposed as soon as it comes into contact with the red iron, and the oxigene which it contains becomes fixed in the metal; as appears from the increase of its weight and the alteration of its substance. The base of inflammable gas being set at liberty, passes quickly through the gun-barrel, and is received into bell-glasses placed for that purpose at the opposite end. On a repetition of their experiments, with all the precision possible, those philosophers discovered, that water contains about six parts of the oxigenous principle with one of the base of inflammable gas; that of consequence this last principle constitutes but a seventh part of the compound; that it is thirteen times lighter than common air; and that it occupies, when at liberty, fifteen hundred times the space which it filled in its aqueous combination.

Water appears to act in the same manner on many other combustible bodies, which it reduces with more or less facility to a burnt state, and to afford uniformly a quantity of inflammable gas. It may be decomposed with zinc, charcoal, or oils; with the last of these, by dropping the water into boiling oil in a retort, the neck of which is immersed under the glasses of a common pneumato-chemical machine. But great caution is necessary to prevent the explosion that takes place when the water rises in the vacuum produced in the neck of the retort by the ebullition of the oil. To determine certainly whether a combustible body, such as a metal, a coal, &c. be capable of decomposing water, immerse a piece of it red hot in-

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to a vessel of water, under a bell-glass filled with the same fluid, and the inflammable gas, which is always disengaged whenever water is decomposed, will be received into the glass. This, namely, the decomposition of water, and the production of inflammable gas, is the reason why bubbles arise when red iron is plunged into water, as has been observed by Messrs Hassenfratz, Stouttz, and D'Hellancourt, of the royal mineralogical school of France. A similar disengagement of inflammable gas, the consequence of the decomposition of water, takes place when a piece of flaming charcoal is thrown into a quantity of that fluid.

These are the newly discovered facts concerning the nature and composition of water. Messrs Lavoisier and Meusnier think, therefore, that this fluid is a compound of about six parts of the oxygenous principle and one of the base of inflammable gas, or, more accurately, of 0.86 of the former body, and 0.14 of the latter; that iron, charcoal, and oils, having a stronger affinity with the oxygenous principle than it has with the base of inflammable gas, enter into combination with it, leave the combustible elastic fluid disengaged, and thus decompose water; that this liquid may be again formed by burning inflammable gas with vital air; that when this process of combustion is carefully performed, a quantity of water is obtained, which answers precisely in weight to the quantity of the two gases, by the combination of which it was produced; that in many chemical operations, water is produced by this combination; and that, therefore, if spirit of wine and oils be burnt under a chimney, proper for condensing their vapours, and fitted to the worm-pipe of a still, the other end of which is joined to a receiver, a quantity

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tity of water is obtained almost always greater than that of the combustible liquid which affords it; because the inflammable gas, disengaged from the liquid, combines with the pure part of the atmospheric air which is decomposed during the combustion*.

These discoveries, and the theory founded upon them, cannot but form one of the most illustrious æras in the history of natural philosophy. As it is of the utmost importance to consider all the consequences of which it admits with all possible care, we shall here add a few observations, in order to convey more distinct and accurate ideas of it.

We have mentioned, that all aeriform fluids owe their gaseous state to the matter of fire or heat combined with them. Inflammable gas depends on the same principle. For as the decomposition of water and its change into inflammable gas always requires an high temperature, and as the more violent the heat applied the more rapid is the change; this gas, therefore, appears to acquire its amazing levity, and to assume the aeriform state, in consequence of a considerable quantity of heat being absorbed by its aqueous base; which is the reason why it can never be obtained

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* However ingenious and conclusive these experiments may appear, philosophers are not yet unanimous in considering water as a compound body. Dr Priestley, in the 11th article of the 1st part of the 78th vol. of the *Philosoph. Trans. R. S. Lond.* gives an account of some experiments concerning the composition of water; from which he is led to conclude, that water is a simple body, which enters into the composition of all elastic fluids; that in the combustion of inflammable gas with vital air, water is only deposited, not produced; and that the calcination of iron by steam, and its reduction by inflammable air, &c. may be explained by the transitions of water and phlogiston.

ed but in a state of extreme fusion. It becomes, therefore, necessary to bestow a particular name on this base of inflammable gas, which when combined with the oxygenous principle, the base of vital air, is susceptible of a solid form, as in the instance of ice. This base being considered as one of the essential principles of water, must be distinguished by a name expressive of that property. We have adopted the word *hydrogene*, or *hydrogenous* principle, as answering the purpose. And we call water a compound of the oxygenous principle, or the base of vital air, and the hydrogenous principle, or the base of inflammable gas. And as there are many inflammable elastic fluids, such as alcohol, æther, volatile oils, &c. when reduced to elastic fluidity; we distinguish this principle of water in its aeriform state by the name of *hydrogenous gas*.

In a future chapter we shall have occasion to review this important subject; in this place it is sufficient to have shown, that water is not a simple, but a decomposable body. Nature in her grand operations effects the separation of principles with much greater facility than art, and by many more ways than art can ever discover or adopt. It is in consequence of its decomposition that water purifies the atmosphere, by pouring into it streams of vital air; that it contributes to the formation of saline matters, of the principles of which pure air is always one; and that such a quantity of inflammable gas is often disengaged from stagnant waters, as sometimes to overload the atmosphere, and to produce igneous meteors, in consequence of being kindled by the electric fluid in its struggles to maintain its equilibrium. Lastly, This

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fine discovery of the component principles of water, its decomposition and recomposition illustrates and explains many of the phænomena of nature, particularly the renovation of the atmosphere, the solution of metals, vegetation, fermentation, and putrefaction; as shall be shown more at large in several succeeding chapters of this work.

C H A P.

C H A P. VIII.

Of Earth in general.

THE philosophers of antiquity believed in the existence of a simple substance, the principle of hardness, gravity, dryness, and fixity, and the base of all solid bodies, to which they gave the name of *earth*. This opinion, founded solely on abstract reasoning and hypothesis, has long been taught in the schools, and is still maintained by a number of philosophers. Paracelsus gave the name of earth to all residues obtained by analysis. But succeeding chemists following the advice of Glauber, to examine residues with as much attention as products, were soon convinced that those were far from being pure earth; and the opinion of Paracelsus was of consequence exploded. Boerhaave having adopted the notion of Paracelsus under some restrictions, observed, that after every analysis, there remained a dry, insipid, heavy, colourless matter; possessing in short all the properties of earth. But these matters, when chemically examined, are found to differ so considerably from one another, that they cannot,

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with any propriety, be comprehended under one general denomination.

Beccher, as has been already mentioned in our account of Principles, admitted three different kinds of earth; vitrifiable, inflammable, and mercurial. Stahl considered the first of these as the only genuine earth; and Macquer follows Stahl in thinking vitrifiable earth the purest and the most elementary.

In order to determine what judgment we ought to form on this matter, let us first examine attentively the properties which chemists agree in ascribing to elementary earth. We find six which have been considered as its distinguishing characteristics; namely, gravity, hardness, insipidity, fixity, infusibility, and inalterability. But all of these properties are found as well in the earth which forms the base of rock-crystal, quartz, and vitrifiable stones in general, as in clays. If then a number of substances, considerably different from one another in many respects, be found to possess in common all the distinctive properties attributed to elementary earth, are we to consider them as so many simple primary earths? Or, shall we rather adopt the opinion of Stahl and Macquer, who, finding vitrifiable earth to possess in a more eminent degree all the properties of elementary earth, consider it as the only genuine primary earth, and the others merely as bodies formed by it in combination with different principles?

However plausible this opinion, however respectable its authors, we cannot agree to consider vitrifiable earth as primary and elementary: 1. Because this earth is not found in equal purity, even in all the stones in which Stahl and Macquer have themselves admitted its existence; for instance, let quartz, rock-crystal,

crystal, and flints, be examined and compared. 2. Because all the discriminating properties of earth are found to belong to many substances which differ from vitrifiable earths only in possessing those characteristics in a less eminent degree. 3. Because vitrifiable earth has not been hitherto shown to be, as some chemists think, the base of all solid matters, and of all the various kinds of earth.

We ought to adopt the following sentiments with regard to this matter. We observe many substances in nature possessing the properties of earths; among which it is impossible to distinguish which is the most simple, as chemists find them all to possess nearly the same degree of simplicity: Besides, though one of these should be demonstrated to be more simple than the rest, it would be farther necessary to show that it enters into their composition, and constitutes the principle of their coherence and solidity. Wherefore, without presuming to determine what is properly elementary earth, we ought to admit the existence of various kinds of earth, and to study their properties, in order that we may recognise and distinguish them whenever chemical analysis offers any of them to our attention, combined or separate.

Chemists have long allowed the existence of several kinds of earthy matters: but the earlier classifications of these matters are faulty, because the properties assumed as characteristics were neither sufficiently numerous nor such as they were certainly known to possess. Such, for instance, is the division of earths into mineral, vegetable, and animal: for though the fixed residues obtained by a last analysis of organized matters, after lixiviating their ashes, be generally destitute of taste or smell, dry and indissoluble, yet these properties are not
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sufficient to intitle them to a place among the earths, as they possess neither inalterability, infusibility, nor simplicity. That substance which composes the dry, solid base of animal bones, and which, from its dryness, insipidity, and insolubility, had obtained the name of earth, has been, within these few years, discovered to be a true saline matter; as we shall show at large in the chemical history of the animal kingdom. And we may with great probability conjecture, that the insipid, insoluble parts, which remain after the last analysis of other animal matters, are of the same nature. The name metallic earths, given to the calces of metals from their dryness, and because some of them are destitute of smell and incapable of solution, does not properly belong to them; for they are extremely fusible, and are, every one of them, compounds, as shall be afterwards shown.

The mineralogists who have treated of the history of earths, have formed a more regular and accurate arrangement of them than chemists, who have considered this subject only in general, and so far as it is connected with the theory of chemistry. Most of the modern philosophers who have attempted a classification of these matters, have characterized them by their chemical properties, and have by that means thrown much new light on the natural history of the mineral kingdom. Wallerius, Cronstedt, and Monnet, have given complete systems of mineralogy on this plan. No chemist has made more numerous experiments on earths and stones than Pott, who has given a methodical arrangement of those bodies according to his own observations. The continued labours of M. D'Arcet, and the many analyses of stones made by Bergman and Bayen, likewise merit the highest praise. We

shall not attempt to exhibit and compare the several classifications of these philosophers: our present object is not to give the natural history of earthy matters, but merely to give the results of the various researches which have been directed to this purpose, with a view to show how many kinds there are of earth considered chemically, and what are the characteristic properties of each kind.

Before proceeding farther, we must observe, that in our opinion no distinction should be made between earths and stones as to classification; because, when we consider them chemically, their substance is the same, and only their aggregation different. Grit-stone, for instance, is but sand agglomerated by the force of aggregation; and sand is nothing but grit-stone, the integrant parts of which are divided, and their aggregation broken: the same chemical properties are common to both.

Pott has divided earths and stones into four classes: the vitrifiable, the argillaceous, the calcareous, and the gypseous. From later discoveries it appears, that the substances hitherto known by the name of calcareous earths, are true neutral salts: gypseous stones have been likewise discovered to be a kind of saline substance. Only two, therefore, of Pott's four classes of stones actually belong to that division of natural bodies. Dr Black, whose name will long mark one of the most illustrious æras in the annals of modern chemistry, by examining the base of Epsom salt, has discovered it to consist of a peculiar substance, to which he has given the name of magnesia, and classed it among the earths. And his opinion has been unanimously adopted by chemists. Bergman, in analysing ponderous spar, has discovered a peculiar earth, to which he has given the

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the name of *terra ponderosa*, and which we call *barytes*.

We think these two last substances ought to be distinguished from earths properly so called, for reasons to be mentioned in the following chapters.

Thus we acknowledge as true earths none but such matters as are absolutely insipid, insoluble and infusible; and we distinguish, by a chemical examination, what substances possess these properties. We admit only two kinds of pure earth, equally simple and equally elementary.

The first is that which constitutes the base of rock-crystal, quartz, grit-stone, flints, and of almost all hard scintillating stones. Its chemical character is to suffer no alteration even from the most violent action of fire, but to retain its hardness, transparency, and all its other properties, to whatever degree of heat it be exposed*. It has been called *vitrifiable earth*, because it is the only species of earth capable of forming, in combination with alkalis, transparent glass. But the name which we prefer is *silice*, derived from that of siliceous earth, which has been likewise given it because it is constantly found in filices.

The second kind of earth which we consider as simple and pure, is pure argillaceous or *aluminous* earth. The following properties considerably different from those of the former species, form its peculiar character. However pure, it is almost always opaque; or if it enter into any transparent stones, those are much inferior in transparency to siliceous stones. It is always disposed in thin layers or laminae, one above another.

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* Some chemists, however, talk of the fusion of rock-crystal as possible by the help of oxigenous gas.

This disposition corresponds to the crystalline form which the former species constantly affects. Though it have no stronger taste than siliceous earth, yet it appears to act in some manner on our organs; for it adheres to the tongue: which property naturalists express by saying, that it sticks to *the tongue*. Its force of aggregation is never so strong as that of the former earth; for which reason argillaceous stones are never very hard, but may be broke by a blow with a hammer, without being cut or struck till they give fire, like scintillating stones. The aggregative force of aluminous earth being so weak, renders it much more susceptible of combination than the other kinds; and accordingly clays are much seldomer found pure than either quartz or rock-crystal. From this it may be easily inferred, why clays are almost always coloured, and why few of them possess all the properties of the aluminous character in any eminent degree. Aluminous earth suffers an alteration from the action of heat, to which siliceous earth is not liable. Instead of remaining, like the latter, unchanged when exposed to an ardent heat, it acquires an addition of aggregative force. It even assumes, in such circumstances, some of the properties of the siliceous, its hardness and aversion to combination. Water acts on aluminous earth, penetrates into its substance, adheres to it, and renders it soft and ductile. The existence of this combination appears from the difficulty with which the adhesion between these two substances is overcome, a strong and long continued heat being necessary to effect a separation between them. The properties which this species of earth possesses of composing a paste with water, and becoming hard by the action of fire, render it a very valuable material in the arts. Lastly, another proper-

ty of aluminous earth, which distinguishes it from the siliceous still more than any of the former, is its capacity of entering into combination with a vast number of other bodies. So subject is aluminous earth to the affinity of composition, that we find it a principle in many compounds: and for this reason we have enumerated and described its properties the more at large, in order that it may be readily recognised when obtained in analyses.

These are the two kinds of earthy matter which appear worthy of being considered as distinct classes, and likewise as elementary substances, since they have not hitherto been decomposed. We are not sufficiently acquainted with their origin, their formation, and their chemical properties, to pronounce, as some chemists have ventured to do, that one of them is simpler than the other, and that the other is nothing but a modification of it. We cannot think ourselves as yet authorised to advance, that the earth of rock-crystal, or siliceous earth, is the base of the aluminous, to constitute which it only needs to be attenuated, divided, and wrought up in a particular manner; because no chemist has hitherto accomplished such a transmutation.

The two earthy matters, of the properties of which we have here taken a general view, are seldom found pure. Rock-crystal is the only body which affords siliceous earth in this state; doubtless because it is excessively hard, and possesses the force of aggregation in an high degree. Even there, it is often coloured by the addition of some extraneous substance. In quartz it is still oftener altered by combination with some colouring matters. But aluminous earth is still seldomer found pure. In short, almost all the earths and stones which naturalists have distinguished by different names,

are compounds of one or two simple earths, or of saline earthy substances, particularly of chalk and magnesia, and sometimes of metallic matters, of which iron occurs the most frequently. To be convinced of this, the reader needs only to cast his eyes on M. Monnet's work, in which he has arranged stones according to their constituent parts. That chemist's plan of arrangement certainly merits no small praise; but while it exhibits to view all the advantages which lithology can derive from chemistry, it at the same time shows how far we are from an accurate and certain classification of stones according to their chemical properties. This subject falls under our discussion in the following chapters.

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PART SECOND.

The MINERAL KINGDOM: MINERALOGY.

SECTION I.

EARTHS and STONES.

CHAP. I.

General View of Mineralogy: General Division of Minerals, and particular Division of Earths and Stones; their various Characteristics.

ALL the bodies of the globe which we inhabit are the objects of natural history. So grand and sublime is this science, when considered with a view to its general scope! so extensive, when traced through all the minute details into which it enters! Its observation ranges from the meteorous phænomena of the atmosphere to the changes which the matters deposited in the strata of our earth undergo. All the bodies scattered over its surface, seas, lakes, rivers, brooks, mountains, hills, valleys, plains, and caverns, engage the attention of him who cultivates natural hi-

story. The inanimate matter of the globe, and the animals inhabiting it, are equally the subjects of his curious inquiry. The eye of genius may indeed comprehend the whole under one grand and extensive view: but humble scrupulous observation confines itself to minute detail; detaches the several parts of this great whole; examines them apart from one another; and thus divides the science into a number of separate branches. Many a man of invincible perseverance, has spent his life in observing and describing the manners and operations of insects; and yet the subject is not exhausted.

The student might therefore be deterred from the study of natural history as too arduous and disgusting a task; but those who have successfully prosecuted the science, have endeavoured to smooth the difficulties of the road to its attainment, by adopting means for rendering it easier of comprehension, and for assisting the memory. These are called *methods*. They consist in arrangements of natural bodies, according to their properties. The characteristics on which such a classification is founded ought to be striking and invariable.

One of the most distinct and important is a division of all natural bodies into three great orders, which are named *kingdoms*; the mineral, the vegetable, and the animal. Though the two last of these seem to possess some leading properties in common, yet the difference between them in point of form and exterior organization is sufficient to make us consider them as separate orders.

Minerals compose the solid mass of the globe, or at least its exterior crust through which the efforts of men have penetrated. Their bulk and dimensions are in-

increased only by the juxta-position of their parts and by their attractive force. They are liable to no change or variation, but such as are occasioned by the mutual chemical action of bodies. And for these reasons they are named *rude, inorganized, inanimate bodies*.

Vegetables, again, increase by the operation of an interior power: they have organs to refine and convert into nourishment, the juices which they derive from the earth and the atmosphere. They spring up, live, and die; by a real generation, they propagate other bodies like themselves.

Lastly, Animals have organs more complex than those of vegetables; undergo more rapid changes; and are, from their superior sensibility and loco-motive powers, much more subject to the influence of surrounding bodies.

The branch of natural history which comprehends the description of minerals, is named *mineralogy*. The first naturalists who attempted classification, arranged minerals into a great many classes. They admitted into their arrangements, as so many distinct orders of minerals, water, earth, sand, soft stones, hard stones, precious stones, figured stones, salts, sulphur, pyrites, minerals properly so called, and metals, &c. Concerning the progress that mineralogy has made since the days of Henckel, one of the first who wrote in a methodical manner on this department of natural history, till the appearance of M. Daubenton, whose classification is a masterpiece of accuracy and precision, the reader may consult the systems published during that period; of which a collection has been made by M. Mongez junior *. He traces the successive improvements which the

* Manuel du Mineralogiste.—Paris, 1784.

the science has received from the labours of Bromel, Cramer, Henckel, Woltersdorff, Gellert, Cartheuser, Justi, Lehman, Wallerius, Linnæus, Vogel, Scopoli, Romé de Lille, Cronstedt, De Borne, Monnet, Bergman, Sage; concluding with those of M. Daubenton, who has accomplished all that could be wished.

To make ourselves acquainted with minerals, the first thing to be done is, to distinguish them into so many classes marked, each by some leading and distinct properties. We shall accordingly divide them into three. Under the first, we shall arrange those stones and earths which are insipid, insoluble, and incombustible: under the second, saline matters, having a stronger or fainter taste, soluble in water, but incombustible: and, under the third, combustible substances, insoluble in water, and affording either a weaker or stronger flame when exposed to the contact of fire, and at the same time not excluded from the access of air.

Most of that part of the mass of our globe with which we are acquainted consists of earths and stones, which by their insipidity, insolubility, and incombustibility, are distinguished from salts and inflammable bodies. Being regularly arranged in strata or layers, they form mountains, hills, and plains; in mountains, they are disposed either in huge shapeless masses, or in inclined horizontal layers; in plains, they are ranged in horizontal strata, and covered with a bed of vegetative earth, produced by the accumulation of the remains of organized bodies. Often, however, such large masses appear under a regular crystalline form in subterraneous cavities or clefts. Most of them appear to have been formed by the action of water; and it is continually dividing, attenuating, and transporting them from

from one place to another, and causing them to undergo many other changes. The natural history of these bodies constitutes *geology* and *lithology*; the first treating of earths, the second of stones: But the two should be united under one class; for all earths, excepting mould formed of the residues of putrefied organized substances, are nothing but stones, the aggregation of which is destroyed; and stones again are formed by the union of earthy matters.

As there are a vast number of different kinds of earths and stones, and a knowledge of them is highly important in science as well as of great use in the arts of life; philosophers have sought to distinguish them from one another, and to give certain directions for recognising them wherever they occur. Ancient naturalists did not think of dividing them into distinct classes by their peculiar properties; they were content with describing their general qualities, and followed the order of their real utility or fancied value. Few of the stones, therefore, mentioned by Pliny in his natural history, can now be found. Modern naturalists, observing the inconveniences which attend this way of describing stones, have adopted a different method, in order to establish more obvious and lasting distinctions. By observing their exterior and sensible properties, they have arranged them into orders, genera, and species; and have thus rendered the study more easy and advantageous.

Form, hardness, interior structure, colour, and the appearance they exhibit when broken, are the properties which have been assumed as characteristics of earths and stones. To these some naturalists have added some of their chemical properties, especially the manner in which they are affected by fire, and the alterations

terations which they suffer from acids. Let us here examine each of these properties, in order to understand the application of the general principles of lithology to the particular history of each of the genera of stones.

§ I. *Form considered as a Characteristic of Stones.*

BY the form of stones, we understand the order and relative arrangement of their surfaces. The eye, at the very first glance on a collection of stones in a cabinet, perceives some of them to be of a regular geometrical figure, and others irregular masses; and observes, that regularity of form is in some instances accompanied with transparency, in some with opacity. Uniform observation has established it as a certain fact, that some species of stones always follow a particular mode of crystallization; while others never appear but in irregular fragments. Several naturalists are of opinion, that all stony matters possess the property of assuming a crystalline form; that some indeed possess it in an higher degree, and display it more invariably than others, but that all have some peculiar crystalline form, which appears in their minutest particles. Such is the opinion of M. Romé de Lille, who has given a very copious and accurate history of the various crystallizations of mineral substances *. That philosopher arranges the forms in which stones and all other mineral bodies appear, under the three denominations

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* Voyez la Cristallographie, 2d edit. Paris 1783.

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of determinate, indeterminate, and confused crystallization; and shows, that there is no mineral substance but appears in one or other of these states. But the truth is, so many of them affect the second mode of crystallization, and the third, which is irregular and difficult to be distinguished, that we cannot gain a sufficient knowledge of the crystalline form of stones, to authorize us to assume this as one of their determinate characteristics. Yet a number of mineralogists have formed general systems of lithology and mineralogy on the principle of the regularity of the form of stones and minerals. Linnæus was the first that adopted this plan of classification; and though he has not entirely accomplished what he proposed in introducing it, he at least directed the attention of succeeding naturalists to this property of stones, and opened the way which has led to all the discoveries which have since been made on this subject.

Such is the state of the present opinions concerning the connection between crystallography and the study of stones and minerals. It explains the formation, and sometimes the nature of these substances; and often helps us to recognize and distinguish them from one another: but it is not adequate to form the basis of a complete system of mineralogy; it is only one of the means to be employed in a classification of minerals. That eminent philosopher M. Romé de Lille, to whose labours we are indebted for so much of our knowledge concerning the peculiar forms of minerals, has not founded his divisions of these bodies on their crystallization alone: instead of making them form the great principle of his classification, he has only examined and described the forms of mineral substances, classed according as their nature is saline, stony, or metallic, and
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according to the various combinations into which they enter.

§ II. *Hardness considered as a Characteristic of Stones.*

THERE are a great many varieties of the aggregation of the component particles of stones, of which lithologists have happily availed themselves to distinguish them from one another. Some have such strength of aggregation, and such a degree of hardness, that they yield not even to the best tempered steel, such as gems or precious stones. Others yield, and may be cut with instruments, but not without difficulty, such as quartz, flints, hard grit-stone, porphyry, and granite. All of these stones when struck smartly against a steel blade produce a great many sparks; which property has gained them the name of *scintillating* or *ignescient stones*. Those sparks are minute pieces broke off from the steel by its collision with the stones, and kindled by the heat which that collision produces: that heat is even so intense, that the particles struck off from the steel are melted; and if they be collected on a piece of white paper and viewed through a magnifier, they will appear a parcel of half-calcined, half-vitrified scoriæ, like the dross of forges. As the stones which act in this manner on steel are not all of the same density, but vary from the hardness of gems and rock-crystal to the softness of sand-stones and vitrifiable breccias recently formed, they must afford a greater or

a less quantity of sparks, according to their respective degrees of hardness.

There are a great many other stones, the aggregative force of which is much less considerable, and which are so soft that they may be easily cut with steel instruments. Some of them, such as marble and alabaster, are susceptible of a fine uniform polish. The rest, and among these almost all argillaceous stones, admit only of an imperfect polish, and always retain a dull, greasy appearance. We can at any time judge of the hardness of those which possess this property in so moderate a degree, and of the polish of which they are susceptible, by wetting their surface. This simple process communicates to them a momentary polish, which disappears in proportion as the moisture evaporates.

It is to be observed, that many other stones besides the class of ignescents produce a real scintillation when struck against steel; the reason of which is, that such stones are mixtures, containing some ignescent parts. Thus, some kinds of marble, and many calcareous breccias, scintillate when struck against steel; because they contain quartzose or flinty particles, intermixed with the calcareous matter of which they are mostly composed.

The gravity of stones is necessarily proportioned to their density. Some naturalists have considered this property as of great importance in a classification of stony matters. M. de Buffon considers specific gravity as one of the best means to enable us to distinguish their particular character. But such nice and accurate experiments are necessary to determine the relative gravities of stones, that this property cannot very well be assumed as the basis of a lithologic method; as plainness

ness and simplicity are highly requisite in the elements of this branch of natural history.

§ III. *Of the Fracture, Considered as a Characteristic of Stones.*

ALL stones when broken display a certain arrangement of their integrant parts, an interior texture and disposition of their particles: but this, so far from being uniformly the same, is infinitely diversified through the various classes of stony substances. To this appearance which stones present when broken, lithologists have given the name of *fracture*. By observing it, we may learn some particulars which will be of use to help us to distinguish their peculiar characters. From a comparison of such observations as have been made on the interior structure of stones, it appears that the several sorts of fracture which they afford may be reduced under certain heads. Some, like glass, give smooth polished surfaces of a curved figure. This is denominated the *vitreous fracture*; it appears very distinctly in rock-crystal, quartz, &c.

Others again display surfaces, which are uniformly smooth, but in their figure alternately convex and concave. The pieces may be neatly re-united. This is called the *conchoidal fracture*. The corresponding convexity and concavity are of various forms and sizes, wide, narrow, round, oblong, deep, shallow, &c.;

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as in several kinds of flint, jasper, agate, and petrofilex.

There is another kind of stones, which when broken exhibit on their new surfaces an assemblage of round projecting points, similar to grains of sand worn by water: this is called the *granulated fracture*, and is very observable in sand-stone. The size and other varieties of the granulation constitute a number of distinctions among the stones of this species, serving to diversify their characters. It is of this species we speak when we say *fine* or *coarse grained* stones.

Lastly, There are many stones, the fracture of which shows them to consist of smooth equal laminæ, disposed one over another. Most of those are stones which bear the name of *spars*; and this is therefore denominated the *sparry fracture*. These laminæ differ from one another in extent, magnitude, thickness, transparency, and position with regard to the axis of the crystallized stone; for all the brilliant stones of this fracture exhibit a real crystallization. Such as are dark and without lustre, are only said to be *lamellated*, not sparry. The disposition of the laminæ, so much diversified in gems, and calcareous, vitreous, and ponderous spars, is what occasions the brilliancy of talc, and the several kinds of feldt-spar, such as eat's eye, the aventurine, the labradore stone, &c.

Some writers on this subject have arranged stones according to their fracture, considered in conjunction with their general form. In the year 1755, Cartheuser published a system of mineralogy, in which he distinguished stones into lamellated, fibrous, solid, and granulated. But fracture alone is insufficient for the principle of a classification of stones; it must be taken

together with the other characteristics which are examined in this chapter*.

§ IV. *Colour considered as a Characteristic of Stones.*

THAT diversity of colours which we observe in stones, is occasioned by the various combustible or metallic substances which enter into their composition. Sometimes the whole stone is of the same colour, and sometimes variegated. The colouring part of stones is generally an accidental property of their nature; the presence of which is not absolutely necessary, and which is liable to great varieties. There are indeed some kinds of stones which are pretty uniformly coloured, such as crystallized gems, schorls, and tourmalines; and in these the colour may be assumed as a characteristic. But as there are other species, and more especially varieties, of which it cannot be considered as a distinguishing property, lithologists therefore do not refer to it as a principle of classification.

Where colour *may* be considered as a characteristic property, we must distinguish between such stones as are all of one colour, and uniformly opaque, or uniformly transparent, and such as are variegated with specks or veins; we must likewise take notice of the number of the colours which appear in any mass of stone; as in marble, for instance, there are sometimes no fewer than six or seven. According to the number

* Voyez L'Introduction a la Sciagraphie de Bergman, par M. Meuzen le Jeune, page 21.

and the disposition of the colours in those bodies, they are distinguished into stones of one, two, three, or four colours, variegated, spotted, veined, punctuated, clouded, flowered, figured, herborised, &c.

V. Alteration produced by Fire, considered as a Characteristic of Stones.

SEVERAL mineralogists, not content with observing the exterior and more observable qualities of stones, have extended their inquiries to their chemical properties, with a view to assume these as grounds of distinction. The particular alteration which any stone suffers from the action of fire, is considered by many lithologists as an excellent mean for enabling us to ascertain its peculiar nature. They have observed, that fire deprives some stones, such as quartz, of their transparency and hardness, without changing their nature or altering their essential properties: others again, such as rock-crystal, have been found to lose not even their density and transparency when exposed to the action of heat: and others have been found fusible and transmutable into glass of various colours; of which kind are schorls, zeolites, asbestos, amianthus, and granites: lastly, there are still many others, such as calcareous stones, which fire deprives of part of their weight, destroying their consistency, and rendering them soluble in water, without melting them. Other experiments, managed with more careful attention, have shown, that some stones lose their colour by fire, and that to some it communicates a deeper shade. Such in general is the

result of the experiments of Messrs Pott, D'Arcet, and many other chemists.

To complete the natural history of stones, it is necessary to take notice of these alterations, and to mark their differences. It appears in general, that simple stones are liable to the least alteration of their properties by fire; and that in proportion as a stone is more or less compound, it is more or less subject to such an alteration. But still the observation of these alterations cannot be of much benefit to lithologists, as the experiments necessary to discover it are tedious and difficult; whereas the properties assumed as characteristics in a classification of stones, should be such as are obvious to the eye, or at least may be discovered by a simple expeditious process.

Sometimes, indeed, when we cannot determine the nature of a stone by observing its external properties, we may have recourse to the alteration which it suffers from the action of fire, by means of the blow-pipe, an ingenious contrivance of Bergman's. Yet notwithstanding the ingenious simplicity of this invention, the necessary apparatus is so incommodious, that it can scarce be rendered portable, so as to be used in a lithologic excursion, but must remain confined to the laboratory *.

§ VI.

* See Bergman on the blow-pipe, at the end of his *Chemical Essays*, translated into English by Dr E. Cullen. London, 1784.

All the apparatus necessary is a blow-pipe, a piece of charcoal, a small silver spoon, and three small phials containing soda, fusible salt, and borax; and the process may be performed in any place where a candle can be sheltered from the wind. Complete apparatus for the purpose, in a box no larger than a book in twelves, are sold at a Mr Brown's, bookseller, near the Strand, London.

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VI. *The Action of Acids considered as a Characteristic of Stones.*

ACIDS are the solvents oftenest used in chemistry. Though we have not yet treated of these salts, yet we must here say a few words of the phænomena which stones exhibit when brought into contact with them. The greater part suffer no alteration from acid salts; but some display a very observable motion, and an agitation somewhat like a slight ebullition, if a drop of the nitric acid be caused to fall through a glass-tube on their surface. This phænomena bears the name of *effervescence*. It is owing to an aeriform substance, which being disengaged from the stone by the action of the acid, rises thro' the acid in a number of small bubbles. That elastic fluid is itself a peculiar acid, disengaged by the more active acid poured on the stone, and is the product of an actual decomposition. All calcareous stones exhibit this effervescence when brought into contact with acids: the nitric acid produces the most powerful effects, and is most commonly employed on such occasions. The disengagement of an aeriform acid is a proof that the matter from which it issues is a saline combination: But as this combination is insoluble, and without any discernible taste, and as it composes most of the exterior layers of the globe of the earth, naturalists always consider it as a stony substance.

Stones may therefore be divided into effervescent and non-effervescent. And a small phial full of nitric

acid becomes of consequence a necessary article in excursions to examine and collect stones. This, together with the magnifier and the steel, are all the instruments which the lithologist needs to carry with him on such an expedition.

Since Bergman recommended the examination of stones by fire with the blow-pipe, they are also assayed with soda, borax, and fusible salt, which act variously upon them according to the differences of their nature, but generally produce fusion in some degree, together with other phænomena. We shall explain this method of analysing stones more particularly in the chapter in which we treat of all the methods of effecting that analysis.

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*The Lithologic Method of M. Daubenton, extracted
from his Tableau de Mineralogie.*

NONE of all the mineralogists who have attempted a methodical arrangement of stones, has given a more accurate or perspicuous classification than M. Daubenton. The ingenuity with which this naturalist, so deservedly celebrated, has contrasted the characteristics of those substances, renders his method more accurate and useful than any before proposed. The properties which he has assumed as characteristics are all invariable and obvious. They are chiefly regularity or irregularity of form; the various degrees of transparency and opacity; consistency or hardness; the polish of which stones are susceptible; the form or respective arrangement of the integrant parts, which occasions the vitreous, conchoidal, granulated, lamellated, and spathose fractures; colours, in those instances in which they are not accidental; a dusky, brilliant, or mildly lucid surface. As it would be impossible to im-

prove upon the perspicuity and accuracy of M. Daubenton's system, all that we shall here do, is, to lay before our readers his division of earths and stones, as he has exhibited it in his *Tableau Methodique de Mineraux* *.

* *Tableau Methodique des Mineraux, suivant leurs differentes natures, et avec des caracteres distinctifs, apparens ou faciles à reconnoitre; par M. Daubenton, Sc. Paris, chez Demonville, Pierres, Debure, Didot l'aîné, Sc. in-8. de 36 pages.*

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FIRST ORDER
OF MINERALS.

SANDS, EARTHS, AND STONES *.

*These Substances melt not in Water, like Salts,
burn not like Combustible Bodies, nor display the
lustre of Metallic Matters.*

CLASS FIRST.

Stones which give Fire with Steel.

Genus I. Quartz.

Crystalline Substance, Fracture vitreous, not lamellated.

Species I. Opaque, or semi-transparent Quartz.

Varieties.	{	1. greasy
		2. grained
		3. lacticous
		4. foliated
		5. crystallized

Species II.

* Here we give only part of M. Daubenton's table; but in the history of salts and combustible bodies, his division of those matters shall be introduced. As we follow that table so faithfully as to copy even the

Species II. Transparent Quartz, ROCK CRYSTAL,

Two pyramids of six sides, with or without a six-sided prism between them.

Varieties.

1. crystallized
2. rough
3. white
4. red. *BOHEMIAN RUBY.*
5. yellow. *OCCIDENTAL TOPAZ.*
6. ruddy, or blackish. *SMOKY TOPAZ.*
7. green
8. blue. *WATER SAPPHIRE.*
9. violet. *AMETHYST*
10. iridescent.

Species III.

the characters in which the several parts of it are printed, we shall here subjoin the beginning of the author's prefatory account of it.

" Since the year 1779, this table has been exhibited in manuscript,
 " in the Hall of the College Royal, during the course of my lectures,
 " and many copies of it have been taken. I have made repeated al-
 " terations, according as I received from others, or acquired by my
 " own observation, new information respecting mineralogy. I have
 " even given up for a time my design of exhibiting on my table the
 " results of a chemical analysis of the different minerals it contains, as
 " I had begun to do, because there has not yet been a sufficient num-
 " ber analysed. My chief object in drawing out this table was to fa-
 " cilitate the study of mineralogy. The best means for diffusing the
 " knowledge of the sciences is to simplify their elements: Methodical
 " arrangements contribute to that end. For though it be impossible
 " to include all the properties of natural bodies, in any classification of
 " them, yet such a classification is useful, convenient, nay, even ne-
 " cessary.

Species III. Quartz in agglutinated fragments, Grit-stone, or Siliceous Grit,

granulated fracture.

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|------------|---|---------------------------------|------------------------|
| Varieties. | { | 1. hard grit-stone | |
| | | 2. friable | |
| | | 3. Levant grit-stone. | <i>Very fine grain</i> |
| | | 4. filtering stone. | <i>Porous</i> |
| | | 5. glittering | |
| | | 6. veined | |
| | | 7. displaying figures of plants | |
| | | 8. coarse grained. | |

Species IV. Quartz in separate grains, SAND,

vitreous surface.

- | | | |
|------------|---|------------|
| Varieties. | { | 1. angular |
| | | 2. round |
| | | 3. moving |
| | | 4. fluid. |

Species

" cessary. In the first volume of my Lectures on Natural History,
 " now in the press, I shall give a particular explanation of my table,
 " in which both the advantages and defects of my arrangement of
 " minerals will be pointed out. Here I shall only observe, that mine-
 " rals are in this table distributed into orders, classes, species, and va-
 " rieties. The distinctive characteristics of each article are printed
 " in *Italic characters*.

" The names in Roman capitals are those which I think most suit-
 " able to the things which they are used to denote: Those in *Italic*
 " capitals are synonymes; the use of which is attended with inconve-
 " niences, and which are inserted only that the knowledge of the mat-
 " ters which they denote may be the easier acquired.

Species V. Quartz in concrete Masses.

Sandy and quartzose Breccias, or Pudding Stones.

Genus II. Semi-transparent Stones,

vitreous fracture, sometimes conchoidal.

Species I. Agates,

of all colours, except milk white, fine red, orange, and green.

Varieties.

- 1. clouded
- 2. punctuated
- 3. spotted
- 4. veined
- 5. onyx
- 6. irised
- 7. presenting the figures of herbs
- 8. exhibiting the appearance of moss

Species II. Chalcedonies,

lacteous transparency.

Varieties.

- 1. reddish
- 2. blueish
- 3. veined
- 4. onyx
- 5. iridescent. OPALS
- 6. round and solid. GIRASOLS
- 7. round and hollow. ENHANCED
- 8. in stalactites
- 9. in sediment
- 10. hydrophanes

Species

Species III. Carnelians,

beautiful red.

- Varieties. {
1. pale
 2. punctuated
 3. onyx
 4. exhibiting figures of herbs
 5. in stalactites

Species IV. Sardonyx,

orange colour.

- Varieties. {
1. pale
 2. veined
 3. onyx
 4. presenting figures of herbs
 5. blackish

Species V. Flints,

gray, white, reddish, blackish.

- Varieties. {
1. with tubercles
 2. in layers

Species VI. The Prasem,

green.

- Varieties. {
1. green
 2. clouded
 3. spotted

Species VII. Jade,

greasy polish.

- Varieties. {
1. whitish
 2. olive coloured
 3. green

Species

Species VIII. Petrofilex,

transparency of wax, conchoidal fracture.

- | | | |
|------------|---|------------|
| Varieties. | { | 1. white |
| | | 2. reddish |
| | | 3. veined. |
-

Genus III. Opaque Stones,

vitreous fracture, sometimes conchoidal or dusky.

Species I. Miln Stone,

more or less porous.

- | | | |
|------------|---|-------------------|
| Varieties. | { | 1. porous |
| | | 2. dense, or full |

Species II. Pebbles,

concentric layers,

- | | | |
|------------|---|---|
| Varieties. | { | 1. spotted |
| | | 2. veined |
| | | 3. onyx |
| | | 4. oculiform |
| | | 5. exhibiting figures of herbs |
| | | 6. concreted into breccias. PUD-
DING STONES |

Species III. Jasper,

vitreous fracture, often dusky, without concentric layers.

- | | | |
|------------|---|-----------|
| Varieties. | { | 1. green. |
| | | 2. red |
| | | 3. yellow |

4. brown

Varieties.

4. brown
5. violet
6. black
7. grey
8. white
9. clouded
10. spotted
11. veined
12. onyx
13. flowered
14. universal
15. fragments united in breccias

Genus IV. Scintillating Spar. FELD-SPATH.

Species I. Feld-Spath, regularly crystallized.

Varieties.

1. in oblique (angled) prisms, of four sides
2. in six-sided prisms, with summits of two planes
3. in ten-sided prisms, with summits of four facets

Species II. Feld-Spath in confused crystals.

Varieties.

1. white
2. pearl-grey. FISH'S EYE
3. red.
4. red, with brilliant spangles.
NATURAL AVANTURINE
5. green
6. blue
7. violet
8. with green and blue stripes.
LABRADORE STONE
9. with stripes of various colours.
CAT'S EYE

Genus

Genus V. Crystal Gems,

transparent and lamellated, not electrifiable by heat alone without friction.

Species I. Red,

Varieties.

1. Garnets
crystallized with 12, 24, or 36 facets. There are also yellow, and brown, &c. garnets
2. The balass-ruby,
rose-colour, octahedral crystals

Species II. Red and orange,

Varieties.

3. Spinell ruby,
fire-coloured, crystallized like the balass-ruby
4. Vermilion,
crystallized like the garnet
5. Hyacinthe-la-belle,
crystallized under 4 hexagonal sides with summits, having 4 rhomboidal facets

Species III. Orange-coloured,

Variety.

6. Hyacinths,
crystallized like the hyacinthe-la-belle

Species IV. Yellow,

Varieties.

7. Oriental topaz,
crystallized in 2 pyramids of 6 facets
8. Saxon topaz,
crystallized in prisms of 8 sides, with summits of 13 facets

Species

Species V. Yellow and green.

Variety. 9. Peridots, *CHRYSO-LITES*,
crystallized in prisms of 6 sides,
with pyramids of 6 faces

Species VI. Green.

Variety. 10. Peruvian emerald,
crystallized in 6 sided prisms

Species VII. Green and blue.

Variety. 11. Aqua-marine,
crystallized like the Saxon to-
paz.

Species VIII. Blue.

Variety. 12. Oriental sapphire,
crystallized like the oriental to-
paz.

Species IX. Indigo.

Variety. 13. Indigo sapphire,
crystallized like the oriental to-
paz and sapphire

Species X. Red and violet *.

Varieties. { 14. Syrian garnet,
crystallized like the garnet
15. Oriental ruby,
crystallized like the oriental to-
paz and sapphire

VOL. I.

O

Genus

* Gems formed without colouring matter are white. *Note of M. Daubenton.*

Genus VI. Tourmalins, Crystal Gems,

composed of laminæ perpendicular to the axis of the crystal, and electrifiable by heat alone without friction.

- | | | |
|------------|---|---|
| Varieties. | { | <p>1. Brazilian ruby,
<i>red in four-sided prisms, with
pyramids of 4 facets</i></p> <p>2. Brazilian topaz,
<i>yellow, crystallized like the Bra-
silian ruby</i></p> |
|------------|---|---|

Genus VII. Tourmalins,

electrifiable by heat alone without friction, laminæ not perpendicular to the axis of the crystal.

- | | | |
|------------|---|---|
| Varieties. | { | <p>1. Tourmalins of Ceylon,
<i>transparent, orange-coloured,
very little channelled on the
surface</i></p> <p>2. Spanish tourmalins,
<i>transparent in a strong light,
orange-coloured, very much
channelled</i></p> <p>3. Tourmalins of Tyrol,
<i>fissures traversing the prism</i></p> <p>4. Tourmalins of Madagascar,
<i>SHORTS OF MADAGASCAR,
opaque, black</i></p> <p>5. Lenticular tourmalins</p> <p>6. Peridots of Ceylon,
<i>yellow and green, very much
channelled</i></p> <p>7. Peridots of Brazil,
<i>yellow and green, very much
channelled</i></p> |
|------------|---|---|

8. Eme-

not elect
long
Specie

Spec

* All
nine-fid
Dauben

- Varieties. { 8. Brazilian emerald,
green
9. Brazilian sapphire,
blue *

Genus VIII. Schorls,

not electrifiable by heat without friction, opaque crystals, or long green semi-transparent needles.

Species I. Crystallized Schorls.

- Varieties. { 1. in oblique prisms, with four
sides
2. in six-sided prisms
PIERRE DE CROIX
3. in six-sided prisms, with sum-
mits of 2 facets, or pyramids
of 3 or 4 facets
4. in prisms of 8 sides, with sum-
mits of 2 facets

Species II. In articulated fragments.

- Varieties. { 1. spathose schorl,
striated with sparry stripes
2. in masses. SCHORL PASTE
*brilliant points in the frac-
ture*

Genus IX. Azure Stone,

opaque and blue.

- Varieties. { 1. purplish blue
2. blue

O 2

CLASS

* All these tourmalins, excepting the lenticular, are crystallized in nine-sided prisms, with summits of three or six facets. *Note of M. Daubenton.*

CLASS SECOND.

*Earths and Stones which neither give Fire with Steel,
nor effervesce with Acids.*

Genus I. Clays,

*when moist they are ductile ; when dry they are polish-
ed by a slight rubbing with the finger.*

Species I. Clays absolutely infusible.

- | | | |
|------------|---|--|
| Varieties. | { | 1. used to make pots for the glass-
house |
| | | 2. for tobacco pipes |

Species II. Clays partly fusible.

- | | | |
|------------|---|-------------------------|
| Varieties. | { | 1. for porcelain |
| | | 2. for English pottery. |
| | | 3. for stone-ware |

Species III. Clays entirely fusible.

- | | | |
|------------|---|-----------------------|
| Varieties. | { | 1. for common pottery |
| | | 2. for delf-ware |
| | | 3. for Dutch tiles |
| | | 4. for tiles |
| | | 5. for bricks |

Genus

Genus II. Shiftus,

argillaceous and foliated fracture.

- Varieties. {
1. black stone
 2. common shiftus
 3. writing slate
 4. polishing stones
 5. green stone
 6. hone
 7. fragments united in breccias

Genus III. Talc,

polished glistering laminæ, without spathose fracture.

Species I. Talc in large leaves.

Variety. Muscovy talc

Species II. In small leaves.

Variety. Mica

Genus IV. Steatites,

feel greasy, like tallow.

Species I. Steatites in layers.

- Varieties. {
1. fine French chalk (de Briançon)
 2. coarse French chalk (de Briançon)

Species II. Compact Steatites.

- Varieties. {
1. soap rock (Pierre de lard)
 2. Spanish chalk

Species III. Lapis Ollaris.

- Varieties. {
1. Como stone
 2. foliated lapis ollaris
- O 3

Genus

Genus V. Serpentine,
the polish and colours of marble.

Species I. Opaque serpentines.

Varieties. { 1. spotted
2. veined

Species II. Semi-transparent Serpentine.

Varieties. { 1. granulated
2. fibrous.

Genus VI. Amianthus,
filaments not calcinable, leaves or flakes lighter than water.

Species I. Amianthus with soft fibres.

Varieties. { 1. with long fibres
2. with short fibres

Species II. Amianthus with hard (brittle) fibres.

Varieties. { 1. Asbestos, easily divisible into parts (mur)
2. Asbestos, not easily divisible into parts (non mur)

Species III. Amianthus in flakes or leaves.

Varieties. { 1. fossil leather
2. fossil cork

Genus VII. Zeolite,
crystallized in divergent radii, or transmutable into a gelly by solution in acids.

Species I. Crystallized Zeolite.

Species

Species II. Compact Zeolite.

- Varieties. { 1. white
2. blue
3. red
-

Genus VIII. Fluor Spar,

fragments with triangular faces, all inclined to each other.

Species I. Fluor Spar in crystals.

- Varieties. { 1. octahædrons
2. cuneiform octahædrons
3. with 14 faces
4. cubical

Species II. Fluor Spar in irregular Masses.

Genus IX. Ponderous Spar,

in rhomboidal fragments, the lateral faces perpendicular to the bases.

Species I. Crystallized Ponderous Spar.

- Varieties. { 1. in rhomboidal plates
2. in octahædrons with acute summits
3. in octahædrons with obtuse summits
4. in hexagonal plates with acute summits
5. in hexagonal plates with obtuse summits
6. in tables
7. in cock's combs (or lenticular)

O 4

Species

Species II. Ponderous Spar crystallized confusedly
BOLOGNA STONE,

Genus X. Ponderous Stone. *TUNGSTEN,*
resembling Fluor Spar in the form of its fragments,
but much heavier ; it becomes yellow in acids.

CLASS THIRD.

*Earths and Stones which effervesce with Acids *,*

Genus I. Calcareous Earths.

Effervescence with Acids.

Species I. Compact.

Variety. Chalk.

Species

* Though modern chemists consider these substances as neutral salts, formed by the union of chalk with the carbonic acid, we subjoin them here after the earthy matters, in order to give a connected view of M. Daubenton's method. Naturalists, who employ in their arrangements none but exterior and striking characteristics, must consider these substances as genuine earths: but in the history of saline matters, they will be viewed in a different light.

Species II. Spongy.

Variety. Stone-marrow.

Species III. In powder.

Variety. Fossil Flour.

Species IV. Consistency of cream.

Variety. Lac lunæ.

Species V. Figured.

Variety. Congealed.

Genus II. Calcareous stones,
indifferent colour and polish.

Species I. Coarse grained.

SPECIMEN.

Limestone from Arcueil.

Species II. Fine grained.

SPECIMEN.

The Thunderstone.

Genus III. Marbles.

Granulated fracture, fine colours and polish.

Species I. Marbles of fix colours.

Varieties.

Varieties. { White, grey, green, yellow, red,
and black.
SPECIMEN.
Marble from Wirtemberg.

Species II. Marbles of two colours.

Varieties. { 15 in number, formed by the com-
bination of 6 colours, 2 together.
SPECIMEN.
white and grey.
Marble of Carrara.

Species III. Marbles of three colours.

Varieties. { 20 in number, formed by the com-
bination of 6 colours, 3 together.
SPECIMEN.
grey, yellow, and black.
Lumachello.

Species IV. Marbles of four colours.

Varieties. { 15 in number, formed by the com-
bination of 6 colours, 4 together.
SPECIMEN.
white, grey, yellow, and red.
Brocatello from Spain.

Species V. Marbles of five colours.

Varieties. { 6 in number, formed by the combi-
nations of 6 colours, 5 together.
SPECIMEN.
white, grey, yellow, red, and black.
Breccias of Old Castile.

Genus IV. Calcareous Spar.

Regular form, spathose fracture.

Species I. Crystallized calcareous spar.

- | | | |
|------------|---|---|
| Varieties. | { | 1. obtuse rhomboidal figure.
<i>Iceland Spar.</i> |
| | | 2. lenticular rhomboidal figure |
| | | 3. lenticular rhomboidal figure, with
6 triangular faces |
| | | 4. acute rhomboidal figure |
| | | 5. with 12 pentagonal faces |
| | | 6. with 3 triangular faces. |
| | | 7. six-sided prism |
| | | 8 six rhomboidal fides, with 6 faces
lozenge-wise |
| | | 9 with 12 scalene triangular faces |
| | | 10 with 12 faces of 4 or 5 fides, and
6 quadrilateral facets |
| | | 11 with 6 hexagonal faces, and 12
facets of four fides. |

Species II. Striated calcareous spar.

- | | | |
|------------|---|-------------------------|
| Varieties. | { | 1. with parallel striæ |
| | | 2. with divergent striæ |

Genus V. Concretions.

Successive coats.

Species I. Stalactite Concretions.

- | | | |
|------------|---|-------------------------|
| Varieties. | { | 1. in columns. |
| | | 2. tabular |
| | | 3. resembling alabaſter |
| 5 | | |

Species

Species II. Concretions by incrustation.

Species III. Concretions by sediment.

Varieties. { 1. by horizontal sediments
2. by rounded sediments

CLASS FOURTH.

Mixed Earths and Stones.

Mixed earths.

Genus I. Sand and clay.

Species. Sand for founders.

Variety. Sand from Fontenai-aux-roses.

Genus II. Sand and calcareous earth.

Genus III. Clay and calcareous earth.

Species. Marle.

Varieties. { 1. marle, Armenian bole
2. marle, terra sigillata
3. stone for taking spots out of cloth
(pierre a detacher)
4. fuller's earth
5. porcelain earth
6. pipe clay
7. potter's clay (terre a faïance)
8. white marle
9. foliated marle
10. marle for manure

Mixed

Mixed stones,

OF TWO GENERA.

Quartz and scintillating spar - -	Granitin.
Quartz and schorl - - - - -	Granitello.
Quartz and steatites - - - - -	Quartzose steatites.
Quartz and mica - - - - -	Micaceous quartz.
Transparent quartz and mica -	Micaceous crystal.
Quartz in grit and gem stone -	1. Garnet on grit-stone. 2. Garnet in grit-stone.
Quartz in grit and mica - - - -	Micaceous grit.
Quartz in grit and calcareous matter	1 crystallized grit. 2 grit in stalactites.
Quartz in sand and opaque stone	sandy and siliceous breccias.
Quartz in sand and schistus	scintillating schistus, HORNSTONE. TRAP.
Quartz in sand and zeolite - - - -	scintillating zeolite.
Scintillating spar and schorl paste	ophites.
Semi-transparent stone, with opaque stone	jasperated agate, or agatized jasper.

Schorl

Schorl and mica - - - - -	{ micaceous spathose schorl.
Schistus and mica - - - - -	micaceous schistus
Schistus and marble - - - - -	Florence stone.
Serpentine and marble	{ 1. green Egyptian marble. 2. sea green marble. 3. green antique marble. 4. green marble of Suza. 5 green marble of Varalta.
Ponderous spar and calcareous matter	{ alkaline ponderous spar.

OF THREE GENERA.

Quartz in sand, schistus and mica	rough wheat-stone.
Quartz, gem, and mica - - -	garnet rock.
Quartzose paste, scintillating spar in small fragments, and schorl	{ porphyry.
Quartzose paste, scintillating spar in large fragments, and schorl	{ serpentine. <i>hard ser- pentine.</i>
Quartz, schorl, and steatites - - -	tuberculous rock.
Quartz, scintillating spar, and schorl	{ granite.

OF FOUR GENERA.

Quartz, scintillating spar, schorl, and mica	{ granite.
---	------------

CON-

CONSIST
GENER

V

Genus

Spec

* M
without
thod co
stones,

CONSISTING OF MORE OR FEWER } universal breccias.
 GENERA, UNITED IN BRECCIAS }

DOUBLE BRECCIAS.

Varieties. { 1. Fragments of porphyry, and paste
 of porphyry.
 2. Fragments of granite, and schorl
 paste.

VOLCANIC PRODUCTS*.

Genus I. Lavas, or Matters formed by Volcanoes;
 volcanic Matters.

Species I. Porous Scoriæ.

Varieties. { 1. in irregular masses
 2. in striped masses
 3. in the form of stalactites
 4. in fragments. LAPILLO
 5. in small fragments.
 POUZZOLANA.
 6. in dust.
 VOLCANIC CINDERS.

Species

* M. Daubenton places volcanic products at the end of minerals, without ranking them under any of the four orders of which his method consists. As their history is usually studied along with that of stones, I have annexed them here.

Species II. Basaltes,

*compact and scintillating, blackish cinerous fracture,
 &c. with brilliant points, without small plates,
 like those of the scintillating schistus.*

Varieties.

1. in irregular masses
2. in balls
3. in tables
4. in prisms of 3, 4, 5, 6, 7, 8,
or 9 sides
5. in articulated prisms

Species III. Glas.

Varieties.

1. in separate fibres.
GLASS GALL.
2. in agglutinated fibres.
PUMICE STONE.
3. in compact masses.
VOLCANIC SCORIA.
LAPIS OBSIDIANUS.

Genus II. Volcanized Matters ; that is to say, mat-
 ters altered by the heat of volcanoes, *appearing to have
 been baked, calcined, melted, or vitrified.*

Species I. Granite.

II. Garnet.

III. Hyacinth.

IV. Mica.

V. Peridot.

VI. Quartz.

VII. Schorl.

VIII. Scintillating spar.

IX. Calcareous Substances.

X. Baked Earths, Tripoli.

STONES, with the Nature of which we are not yet sufficiently acquainted to reduce them under certain Classes.

Jargon of Ceylon,

crystals in rectangular prisms, with pyramids of 4 triangular faces.

The name of Jargon appears to be given to many stones, the particular structure of which is hitherto unknown.

Macles,

in square or cylindrical prisms, the transverse section of which exhibits a blue cross.

The macle has been considered as a schorl; but the opinion has not been proved.

White Crystals,

in flattened prisms with 10 sides, with two summits of four faces, one of which forms a concave, the other a convex angle.

Violet or green Crystals,

rhomboidal, with two facets instead of two opposite angles.

These white, violet, and green crystals, have obtained the name of Schorls, although they do not appear to be of the same nature with schorls.

C H A P. III.

Of the Classification of Earths and Stones according to their chemical Properties.

THOSE chemists who have engaged in the study of minerals, have endeavoured to establish distinctions among them founded on their chemical properties. And though a sufficient number of earths and stones has not yet been examined, to enable us to form very accurate or complete arrangements of them on these principles; yet it is certainly an object of importance to the student of mineralogy to know the present state of chemical science respecting these substances, and what advantage the mineralogist can derive from it in arranging them.

Of all the philosophers who, since Cronstedt, have attempted to arrange earths and stones by their chemical properties, Bucquet, Bergman, and Kirwan, have been the most successful, and have given the most complete systems. As each of these gentlemen has followed a peculiar mode of arrangement, and as each of their methods possesses some undeniable advantages,

we

we shall here lay before our readers successive views of the three systems, and shall at the same time point out their several defects.

§ I. *Of the Chemical Division of Earths and Stones proposed by BUCQUET.*

BUCQUET, after many laborious researches with a view to this object, at length formed, a little before his death, a system of earths and stones, on the compound principle of their chemical properties and their exterior characteristics, as observed by naturalists, which he had resolved to follow in his future courses of lectures. In repeated conversations with him during the lingering illness which ended in his death, I obtained a full account of that method; which was communicated to the public in the first edition of this work. I shall now again give it as it then appeared, only adding a few notes, to take notice of the improvements which this branch of the science has received since the year 1779.

According to Bucquet, earths and stones should be arranged under three divisions: the first comprehending simple earths and stones; the second, compound earths and stones; and the third, mixtures of earth and stone.

Simple earths and stones, in a state of purity, are insipid, dry, hard, insoluble, and infusible. Whenever any of them appear to possess these properties in a less

perfect degree, more especially when any of them appear susceptible of fusion, they are to be considered as not pure, but alloyed by the mixture of some extraneous matter. Such as are pure, admit not of decomposition by chemical analysis; but the number of pure stones is much more scanty than Bucquet thought it.

Compound earths and stones are to be regarded as combinations of the simple earths with saline or metallic substances. These combinations have been effected by the operation of fire or water in the great laboratory of nature. Their chemical characteristics are, to melt easily, to suffer vitrification from the action of fire, and to be separable into several simple substances by the action of solvents, more especially by the action of acids.

Mixed earths and stones are easily distinguished by inspection. They seem to be formed by the irregular aggregation of several earths and stones, both simple and compound. To analyse them, the several different matters of the irregular aggregate must be divided and examined each by itself. Their peculiar natures may be then certainly determined by chemical experiments.

DIVISION I.

Simple Earths and Stones.

THESE are divided into four orders.

ORDER I. VITREOUS STONES.

THESE are extremely hard, and perfectly transparent; of a vitreous fracture; give fire with steel; and

and suffer no alteration in transparency or hardness from the action of heat.

This first order contains two genera; rock crystal and vitreous precious stones.

Genus I. *Rock-Crystal.*

ROCK-CRYSTAL exhibits all the properties of vitreous stones in the most eminent degree. Its fracture, which is similar to that of glass, distinguishes it from the following genus.

It may be subdivided into species.

1. *By the Property of Form.*

Species.

1. Insulated hexahædral crystals, with two hexahædral pyramids. The Abbé Rochon has observed, that these produce a double refraction.
2. Hexahædral crystals, united in groups, with one or two points.
3. Tetrahædral, duodecahædral, flattened, &c. crystals. Those of which the facets are varied and irregular are always hexahædral.
4. Rock-crystal in masses, from Madagascar. It produces only a single refraction.

2. *By the Property of Colour.*

5. Reddish rock-crystal.
6. Smoky crystals.
7. Black crystals.
8. Yellow crystals.
9. Blue crystals.
10. Green crystals.

3. *By accidental Circumstances.*

Species.

11. Hollow rock-crystal.
12. Containing water.
13. One crystal inclosed within another (*emboîtés*).
14. Rounded ; pebbles from the Rhine.
15. Incrusted with metallic calces.
16. In *gæodes*.
17. Containing amianthus.
18. Containing schorl.
19. Incrusted with pyrites.

Their formation by water is proved,

1. By their transparency.
2. By the form of small crystals.
3. By the inclosure of one crystal in another.
4. By their inclosing substances alterable by fire.

They are cut and polished into vases and toys.

Genus II. *Vitreous Precious Stones.*

THE precious stones which we rank under this genus, have all the properties which characterize rock-crystal, and more especially its inalterability by fire. Though this may seem an inversion of the natural order, and Bergman informs us, that he found these stones to be compositions of several different matters; yet in their hardness, their transparency, and the manner in which they are affected by fire, they differ but little from rock-crystal ; but they are inferior in hardness, their colour is not so clear and lively, and their fracture is lamellated. The differences among precious stones, particularly with regard to the manner in which

which they are affected by fire, induced Bucquet to separate them, and to arrange them among those of the orders of stones to which they have the nearest resemblance.

The four precious stones which we distinguish by the denomination of vitreous, are,

Species.

1. The oriental topaz.
2. The hyacinth.
3. The oriental sapphire.
4. The amethyst.

M. Daubenton has always considered this last as a quartz crystal.

ORDER II. QUARTZOSE STONES.

THESE are not so hard or transparent as the former; their fracture is vitreous; and they give fire with steel. Heat deprives them of hardness and transparency, and reduces them to a white opaque earth *. Under this order we arrange four genera.

Genus I. *Quartz.*

It possesses all the above characteristics.

P 4

Species.

* It was on account of their being liable to alteration by fire, that Bucquet distinguished quartz from rock-crystal, and arranged them under a particular genus. He likewise observed, that this stone dipped in water, after being for several times successively heated red hot, communicated to that fluid a degree of acidity. Future experiments will determine the certainty of this fact. A.

Species.

1. Transparent quartz, crystallized in hexagonal pyramids; its prisms either not observable, or at least very short.
2. Transparent quartz in masses.
3. Opaque or lacteous quartz.
4. Greasy quartz.
5. Carious quartz.
6. Green, blue, or violet quartz; prism of amethyst.
7. Yellow quartz, of a lamellated fracture.

Topaz { Saxon.
 { Brazilian.

These topazes possess all the characteristics of quartz.

Genus II. *Flint, Agate.*

FLINTS and agates are small round masses, generally opaque, sometimes semi-transparent, either hollow or solid, of various colours, and disposed in strata;—in chalk, as is the case with flints; or in clay, as agates. Their fracture is sometimes scaly.

Species.

1. Grey flint.
2. Yellow flint.
3. Red flint.
4. Corneous flint; gun-flint.
5. Brown Egyptian flint.
6. Transparent clouded flint; German agate.
7. Red agate; male cornelian.
8. Pale red agate; female cornelian.
9. Brown or yellow agate; sardonyx.
10. Agate

Species.

10. Agate-onyx, in concentric laminæ.
11. Laminated agate, in horizontal layers; but the appearance of the laminæ, and their disposition with regard to the figure of the stone, depends in a great measure on the manner in which it is cut.
12. Figured agates. { Dendrites; herborized agates *.
Anthropomorphites.
Zoomorphites.
Uranomorphites.
13. Agate, apparently mouldy; marked with small green points, generally owing to mosses.
14. Agate of four colours; elementary.
15. Grey agate; grey chalcedony.
16. White, lacteous, or chalcedony agate. { in layers.
in stalactites.
round, cacholong.
17. White agate, with a mild reflection of the light. { Lapidaries agate, mild lustre.
Cat's eye.
Oculus mundi, or hydrophanes.
Opal.
Girasol.
18. Brown agate, with brilliant gold-coloured points. Avanturine.
19. Oriental agate.
20. Agate containing water (Enhydre).

The formation of quartz, agates, and flints, is owing to water, as is proved,

1. By

* M. Daubenton has shown, in a memoir read to the Academy, that herborized stones contain very fine mosses, or small grains of black iron ore. A.

1. By their form.
2. By their layers.
3. By their mosses.
4. By their containing water.
5. By the organized matters mixed with them, as in the mossy or mouldy agates.

This also appears from the circumstances and properties of the gæodes. These are stone boxes, filled with crystals: they contain flint and quartz arranged in concentric layers.

Genus III. *Organic Matters converted into Silica, or Agate.*

THESE are distinguished from the other genera of this order, by possessing the characteristic properties of quartzose stones under an organic form *.

Species.

1. Wood petrified, but still fibrous, and susceptible of polish.
2. Wood, the texture of which indicates its particular kind. Fir.
3. Sea-urchins and madrepores converted into flint.
4. Shells converted into agate.
5. Carpolites: these have been mistaken for petrified

* It would perhaps be a much more natural mode of division, to arrange under a distinct class, all such animal and vegetable substances as have suffered alteration from lying under ground. The name of that class might be fossils, and it might be placed at the end of the organic kingdoms.

Species.

trified fruits; they are properly small *ludus belmontii* scilicified.

6. Entrochites.

7. Lapis frumentarius filiceus.

This last stone gives fire with steel, but does not effervesce with acids. It seems to be formed by an assemblage of cornua ammonis divided perpendicularly to their volutes.

There are two opinions concerning petrification. Some think that organized bodies are entirely transmuted into stone: others are of opinion, that the void spaces formed by animal substances in soft earths, and the interstices in the fibrous texture of vegetables, are gradually filled up by an accumulation of earthy matter. But we can pretend to no certain knowledge of the cause of this phenomenon. Vegetable matters are observed to become almost always quartzose, and scarce ever calcareous; while animal substances, on the contrary, become generally calcareous, and seldom quartzose *. From this fact we may almost conclude, that no real petrification takes place, and that organized bodies are not converted into stone: For, 1. Shell-fish and madrepores only lose their mucilage or animal gluten, by putrefaction, and are reduced to calcareous skeletons, which existed during the life of the animals: 2. What is said to be petrified wood, is nothing more than an accumulation of vitrifiable earth in moulds formed

* Since the discovery of the fluoric acid gas, which possesses the property of depositing quartzose earth, some naturalists have conjectured, that petrification may be produced in a similar manner. But this is to be regarded as mere conjecture, till such time as it be shown that there exists in the interior parts of the earth an acid which maintains quartzose earth in a state of solution.

formed by putrefied vegetables. As the fibres of the vegetable body are gradually destroyed by putrefaction, a quantity of quartzose earth is deposited by the water in the space which they occupied: a quartzose stone is thus formed of the very figure and texture of the vegetable body, but not a particle of that substance enters into its composition.

Genus IV. *Jasper*.

JASPER possesses all the characteristics of quartzose stones. It is infusible, but loses its aggregation by fire; it is extremely hard, opaque, and variegated with divers colours; its fracture is dusky and vitreous. It is not often found arranged in beds; it generally composes considerable masses or veins in rocks: It is also found in small round lumps. Most specimens of jasper that we have seen are mixtures of quartz and chalcodony. It sometimes contains calcareous spar.

Naturalists have divided jasper into a great many species. These may be reduced to the following.

Species.

1. White jasper.
2. Grey.
3. Yellow.
4. Red.
5. Brown.
6. Green.
7. Veined.
8. Spotted.
9. Green, with red points; bloody jasper.
10. Flowered.

Jasper

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Species.

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Varieties

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3

* M

Jasper is used for making toys, particularly cups and seals. There are many antique engravings on stones of this kind.

Genus V. *Grit, or Free-stone.*

GRIT-STONE is opaque, of a granulated fracture, much softer than quartz or flint; it is found in large masses, of various degrees of hardness, and sometimes finer, sometimes coarser, grained.

Species.

1. Grit crystallized in rhombi. M. de Laffone has shown that these owe their form to the chalk incorporated with them *.
2. Grit in the form of cauliflowers.
3. In stalagmites.
4. White.
5. Grey.
6. Red.
7. Black, or brown.
8. Veined.
9. Figured, or herborised.
10. Grit, of which the aggregation is destroyed; sand.

Sand appears under the following varieties:

Varieties.

1. Quick-sand.
2. Angular sand.
3. Sand rounded by the action of water.
4. Pure

* Memoirs of the Academy of Sciences for the year 1777.

Varieties.

4. Pure white sand.
5. Micaceous sand ; glare.
6. Yellowish, argillaceous ; founder's sand.
7. Ferruginous sand ; yellow.
8. _____ black.
9. Blue sand ; from copper.
10. Violet sand ; from tin.
11. Auriferous sand.

ORDER III. ARGILLACEOUS EARTHS *and* STONES.

THESE are greasy ; clammy, or pliant ; stick to the tongue ; foliated ; frequently coloured ; and disposed in large masses, and in layers.

Their force of aggregation is less than that of quartzose stones ; but they have a greater tendency to combination, and are therefore often altered. Heat contracts and hardens them, so as to give them the appearance of quartzose stones, and cause them to give fire with steel as well as those. Water reduces them to a paste, divides, and purifies them ; they absorb water, and retain it with such force of combination, that they cannot be again totally deprived of it.

Part of the substance of these stones combines with acids. Some chemists have taken clay to be nothing but siliceous earth altered by the vitriolic acid ; but that opinion has not yet been fully proved.

Many naturalists have entertained an opinion, that vitrifiable earths, after being long exposed to the agency of water, air, and heat, are separated and reduced into fine soft particles, capable of combination with water, and thus pass into the state of clay. This theory being founded on some accurate observations, merits more

more respect than the former: But the evidence of neither amounts to demonstration.

These two properties of mixing with water so as to compose a ductile paste, and again becoming hard by the action of fire, render clay fit for being wrought into tiles, bricks, pottery, delft-ware, and porcelain: and an account of these makes a part of the history of this kind of earths.

Naturalists have described a great many kinds of stones as belonging to this order; but they have confounded among them many false clays and compound stones; such are, of the last, serpentine, zeolite, trapp, &c.

The name of *clay* properly belongs to none but such earths as are hardened by fire, are diluted in water, and combine with the sulphuric acid to form alum.

Macquer having examined a great many of them, found none absolutely pure *. Many of them owe their colour and fusibility to their being mixtures of various combustible and metallic substances.

Bucquet divided them into four genera.

Genus I. *Soft Ductile Clays.*

THESE, when dug from the bed or quarry, may be kneaded; but they become dry in the open air.

Species.

1. White clay; pipe clay.
2. Sandy clay,
3. Clammy blackish clay; for white pottery.
4. Clay, with a mixture of mica, kaolin; partly fusible; for porcelain.
5. Me-

* Academy of Sciences, 1758.

Species.

5. Metallic clay, fusible; terra sigillata; Armenian bole.
6. Pyritous clay; fusible; blue, green, marbled; used in common pottery.

Genus II. *Dry, Friable Clays; Clay of Tripoli.*

ALL those clays which Bucquet ranked among the tripolis, are dry in the interior parts of the earth. They are all found in beds or layers, often very thin, and arranged one above another. All of them crumble down into dust under the finger, and absorb water readily; they likewise stick to the tongue.

Species.

1. Dry, grey, foliated clay; fullers earth.
2. Red tripoli. Some people take this to be a volcanic product.
3. Grey tripoli.
4. Black tripoli.
5. Rotten stones of an olive grey colour.

Genus III. *Schistus.*

SCHISTI are foliated stones which split readily into plates: they are a mixed fusible substance; they are placed in huge masses in the bowels of the earth, and always in an oblique direction. Almost all quarries of schisti exhibit on their exterior surface and in the uppermost layers impressions of plants of the rush and fern kinds, &c. of shells, fishes, or insects, &c.

Species.

1. Black schistus, tender; ampelite.
2. Fissile schistus; slate.
3. Black, hard schistus; writing slate.
4. Red, brown schistus, &c.
5. Schistus marked with impressions of vegetable or animal bodies.
6. Very hard schistus, used for whetting razors.

Genus IV. *Feldt-Spar.*

It exists in the form of rhomboidal plates; its fracture is spathose, and it gives fire with steel: It is for this reason called *scintillating spar*. Though harder than the schisti, it is fusible. Bucquet thought it to be an argillaceous stone, coloured by a mixture of iron. M. Monnet considers it as a compound of quartz, clay, magnesia, and a small portion of calcareous earth. Its being but little known is the cause of this diversity of opinions concerning its nature. A more accurate examination must determine its true character*.

Vol. I.

Q

Species.

* Father Pini, an Italian naturalist, was the first who described crystallized feldt-spar. Since his discovery, it has been found in many places in France. Very regular feldt-spar crystals are found at Roanne en Forez. I have given a minute description of that which is found in the Alençon granites, and is one of the most regular and beautiful with which I am acquainted, in my *Memoires de Chimie*. A.

Species.

1. Prismatic feldt-spar *.
2. White feldt-spar.
3. Red feldt-spar.
4. Green feldt-spar.
5. Blue feldt-spar.

ORDER IV. FALSE CLAYS.

THESE resemble clays only by having a foliated texture, and greasy appearance; some of them indeed harden by fire.

They differ from clay, as not being fit for composing a paste with water, and as being most of them fusible in fire. They combine with the vitriolic acid to compose a salt in the form of needles, which suffers no alteration from air, but is soluble in four or five parts of water, and does not swell in fire; in a word, is not alum. Bucquet, who had examined a great many of those stones, gave these as their characteristics: but as they are very little known, they may still be ranked near the clays †.

Genus

† M. Daubenton ranks this among the scintillating stones. It is distinguished by three characteristics from every other species of stones; its texture is spathose; it yields a mild or *chatoyant* lustre; and it gives fire with steel. With these characteristics, this genus must contain more species than Bucquet ascribed to it. M. Daubenton included under it the fishe's eye, the avanturine, and the labradore stone. A.

* The Abbé Mongez, in his Introduction to Bergman's Sciagraphy, observes, that these stones might be with more propriety named *magnesian stones*. I should willingly agree to use that name; but I believe a number of experiments are necessary before we can receive it as expressive of their nature. A.

Genus I. *Lapides Ollares, hard.*

Their texture can scarce be called foliated; their appearance is greasy; and they are susceptible but of an indifferent polish.

Species.

1. Grey, Swedish lapis ollaris.
2. Greenish lapis ollaris; Swedish colubrine.
3. Yellowish lapis ollaris; Chinese soap-stone.
4. Bright green lapis ollaris; jade. Bucquet thought the nephritic and Otaheitean stones to be varieties of the jade. The jade is very hard, and gives fire with steel. Bucquet appears to have followed Pott in placing it among the lapides ollares.
5. Dirty green lapis ollaris; colubrine.
6. Serpentine. A stone of a deep green, or rather blackish colour, with black spots or veins, like a serpent's skin. On account of its appearance, we have placed it at the end of the lapides ollares; it seems to be a compound.

Genus II. *Soft Lapides Ollares; Steatites, or Smectites.*

THESE are more of the nature of soap than the foregoing genus. They may be easily cut; they froth with water, and some of them have externally a striking resemblance to soap.

Q 2

Species:

Species.

1. White, compact steatites; Briançon chalk.
2. Bright Briançon chalk; the druggists Venice. talc.
3. White, Norwegian steatites.
4. Red marbled Norwegian steatites.
5. Reddish Norwegian steatites.
6. Green compact steatites from Norway.
7. Green and red steatites from Norway.
8. Green, foliated; soft colubrine of Norway.
9. Black steatites; used by stone-cutters.
10. Sparkling grey steatites; plumbago, molybdena, and very improperly black lead. Plumbago being reduced to powder, and wrought into a paste with a mixture of isinglass, is inclosed in small cylinders, which are cut to a point at one end, and used as pencils or crayons *.

Genus

* Since the death of Bucquet and the first edition of this work, Messrs Scheele, Grahn, and Hielm, have very successfully investigated the nature of plumbago: they have found it to be a kind of sulphur, formed by the combination of the carbonic acid with phlogiston. We shall give its history after that of sulphur. The same chemists, more especially M. Scheele, have a very proper distinction between plumbago and molybdena, which former naturalists had always confounded together. M. Scheele considers molybdena as a compound of sulphur with a certain acid, to which he gives the name of the *molybdenic*. (See the history of sulphur.) It is plumbago which is used for pencils. F.

In England, the plumbago used for pencils is not ground to powder and mixed with isinglass; but cut into long slender pieces and inclosed in wood. Those described by the author are an inferior kind.

Genus III. *Talc.*

It consists of polished glittering plates, disposed one over another, and of a gelatinous transparency. These laminæ or plates are sometimes crystallized in an hexagonal form, or in sections of six-sided prisms. A strong fire melts it into coloured glass.

Species.

1. Talc in large transparent plates; Muscovy glass.
2. Talc in very small silvered spangles.
3. Talc in very small golden spangles. These two kinds are used to dry writing, under the name of *gold or silver powder*.
4. Talc worn into the form of pebbles.
5. Talc in black spangles.
6. Talc in mixed brilliant spangles.

Genus IV. *Amianthus, Asbestos.*

THE stones of this genus consist of fibres or threads disposed parallel to one another, or interwoven like the texture of a web. Those threads are sometimes stiff, sometimes flexible; and they differ from one another in colour, length, and thickness. The ancients spun them, and made of them a kind of cloth, to which they gave the name of *incombustible linen*, in which they burnt the bodies of the dead, in order to preserve their ashes, &c.

Amianthus melts, in a strong fire, into an opaque coloured glass.

Species.

1. Hard grey asbestos, with parallel threads; ligneous asbestos.
2. Hard green asbestos, with parallel threads.
3. Hard green asbestos; its threads in bundles.
4. Asbestos, with diverging fibres.
5. Hard asbestos, with soft fibres.
6. Hard amianthus, with parallel greenish fibres.
7. Hard amianthus, with parallel white fibres.
8. Amianthus in bright white bundles.
9. Amianthus in hard yellowish bundles.
10. White flexible amianthus.
11. Grey amianthus.
12. Mountain flesh.
13. Mountain leather.
14. Mountain cork.

DIVISION II.

Compound Earths and Stones.

THESE cannot be distinguished by ocular observation from those of the former division. As to the nature of their composition, they are formed of an homogeneous matter, almost always coloured, generally opaque, but sometimes transparent; most of them are regularly crystallized. They are distinguished into genera by form and colour. They are all very fusible, and afford glass of various kinds. Their fracture is sometimes vitreous, sometimes scaly. In these substances nature has combined together earths, salts, and metals.

Buc-

Bucquet divided these stones into two orders: Under the first he comprehended earths and stones compounded with water, which he characterised as products of that element. This order again he divided into two genera, namely, ochres and zeolite. Under the second order he reckoned schorl, macles, trap, azure stone, fusible precious stones, volcanic crystals, volcanic glass, and pumice stones: these eight kinds of stone he considered as formed by the action of fire. We have undertaken to give an account of the ideas of that celebrated chemist concerning the nature and classification of stones; but as the distinction between these two orders is not established by a sufficient number of conclusive facts, and as M. Bucquet himself offered them only as hints, we shall here give the history of these genera successively, without dividing them into orders.

Genus I. Ochres.

OCHRES are less easily diluted in water than clays; they are friable and soil the fingers; they are coloured by metallic matters, generally by iron. When exposed to a strong fire, they assume a deeper colour: violent heat melts them. They are used in painting.

Species.

1. Yellow ochre.
2. Red ochre, blood coloured.
3. Green ochre; Verona earth.
4. Brown ochre; Umber earth.

Genus II. *Zeolite.*

THE zeolite, first described by Cronstedt, is a stone composed of needles diverging from a common centre. It neither gives fire with steel nor effervesces with acids: When exposed to fire it swells and produces a white opaque glass resembling enamel. By distilling it in a retort, a considerable quantity of water is obtained. The residue, according to Bergman, consists of siliceous, aluminous, and calcareous earth. Bucquet, who analysed it, mentioned his having found in it very little siliceous earth, and a particular kind, neither aluminous nor calcareous; which with the sulphuric acid afforded a salt crystallized in small shining plates, resembling the boracic acid, and to which he thought proper to give the name of *zeolitous earth*. These two earths are crystallized together by the help of water, which forms more than an eighth part of the composition: for, from an ounce of white zeolite, from the island of Ferro, M. Bucquet obtained a dram and an half of water *. The property of composing a jelly with various acids is not peculiar to it; azure stone, tin, and several iron ores, &c. are capable of a similar composition †. Its origin and formation are unknown; abundance of it is found among the products of volcanoes.

* Voyez les *Memoires de Savans etrangers*, Tome IX. p. 576.

† M. Pelletier, apothecary, a scholar of M. d'Arcet, has given in the *Journal de Physique* (1782, vol. XX. page 420.) a memoir on the analysis of the zeolite of Ferro. He has found, by the most accurate experiments, that 100 grains of this stone contain 20 grains of aluminous, 8 grains of calcareous, and 50 of siliceous earth, and 22 grains of water. Consult that memoir. F.

noes. There is great plenty of it in the isle of Ferro. We are acquainted with five kinds of it.

Species.

1. White zeolite, in transparent fascies.
2. White zeolite, in compact fascies.
3. Red zeolite.
4. Green zeolite.
5. Blue zeolite.

Neither the red, the green, nor the blue, has yet been examined.

Genus III. *Schorls.*

SCHORL is a dark-coloured stone, generally violet, black, or green, very seldom white, sufficiently brittle, and capable of giving fire with steel. It melts easily into a black opaque glass; it is, according to Bucquet, a combination of iron and aluminous earth. Bubbles have been found in the interior part of schorls, similar to those in the flags of glass-houses.

Its origin is not very well known. Some people think it a volcanic product, because it is often found in places which have felt the ravages of fire; but it is likewise found among matters which have been long exposed to the action of water.

Species.

1. Violet schorl, in crystals.
2. Violet schorl, in fibrous masses.
3. Black schorl, in prisms of 4, 6, 8, or 9 sides, with pyramids of 2, 3, or 4 faces, like the violet schorl.

Spe-

Species.

4. Black schorl, in masses.
5. Green schorl, in lamellated masses.
6. White schorl, somewhat blueish.
7. Electric schorl, of a yellowish red, tourmaline.

Genus IV. *Macles*.

UNDER this name we comprehend a genus of stones, of a prismatic form, opaque, dirty-coloured, and generally of a regular figure. By analyzing them M. Bucquet found them to be of a nature nearly resembling that of schorls, namely, a compound of iron and aluminous earth.

Species.

1. Tetrahædral macle, the section of which exhibits the figure of the cross. It is found in a kind of hard deep blue schistus of Brittany, to which it adheres strongly: it is very brittle, and when broken, exhibits on its transverse section two blueish lines, cutting each other in the form of a cross. Sometimes the middle of the prism appears to be full of a matter resembling that of the gangue.
2. Stones of the cross; hexahædral prisms, articulated and crossed in the middle like the arms of a cross; these are found in the leaves of yellow mica; the two arms never cross each other at right angles.

Genus

Genus V. *Trap.*

TRAP is an hard stone, fine grained, of a foliated fracture, and angular, like the steps of a ladder. Its colour is a deep green, approaching to black, often inclining to the colour of ochre; it is very ponderous, and gives fire with steel. It melts into a blackish glass, and is always covered with a kind of crust softer than itself. It is a compound of aluminous earth and iron: According to Bucquet, iron exists in it, in the proportion of twenty-five pounds to the quintal, so that it might be considered as an iron ore. M. Daubenton thinks it a schistus containing quartz in sand. There is only one kind of trap known,—that which we have described.

Genus VI. *Azure Stone ; Lapis Lazuli.*

THIS stone is classed along with the preceding genera, on account of its colour, the fineness of its grain, and the quantity of iron which, from an analysis, it appears to contain.

Species.

1. Oriental azure stone.
2. Azure stone, of a pale blue, and often purplish.
3. Armenian stone, clouded with white and pale blue.

The azure blue used in painting, which is one of the most fixed and permanent colours known, is a preparation of this stone.

Genus

Genus VII. *Fusible Crystal Gems.*

M. BUCQUET, in consequence of observing the differences of the various kinds of gems, or precious stones, as to chemical properties, was induced to arrange them separately under those divisions and orders to which they seemed most properly to belong. Those which we are going to introduce in this place are evidently compounds. Bergman found them to consist of various substances, such as siliceous and aluminous earth, lime, and iron; all of them are fusible and composed of laminæ. Their fracture is lamellated.

Species,

1. Aqua-marina.
2. Emerald.
3. Chrysolite.
4. Ruby.
5. Vermilion, or Bohemian garnet.
6. Garnet.

Genus VIII. *Volcanic Crystals.*

UNDER this genus Bucquet comprehended all such stones as are of a regular form, transparent, coloured, and similar to crystal gems, but possess not the hardness or brilliancy of these last. They are found in cavities lined with small sparkling particles of the same nature, agglutinated together. They are met with in the neighbourhood of volcanoes. We admit three species of them.

Species.

Species.

1. Volcanic chrysolite; polyhædral crystals of a golden green.
2. Volcanic hyacinth, polyhædral crystals of an orange yellow.
3. Volcanic garnets. These strongly resemble single garnets; but they are irregular, and, as well as the two foregoing species, scattered among brilliant lavas.

Genus IX. *Pumice-Stones.*

MOST pumice-stones appear to be a collection of vitreous threads wound up together, nearly like yarn on a clue. The pumice-stone is really a combination of various substances which have been reduced to fusion by the volcanic heat.

Pumice-stones may be divided into four species; each of which has many varieties.

Species.

1. White fibrous pumice-stone.
2. Coloured fibrous pumice-stone.
3. Light cellular pumice-stone.
4. Compact cellular pumice-stone.

Genus X. *Volcanic Glass.*

THE glass melted and discharged by volcanoes is a mixture of earthy and saline matters, coloured with iron.

iron or some other metallic substance, It is actually a natural chemical combination effected in the dry way.

Species.

1. Greenish cellular glass.
2. Blackish cellular glass, or in agglutinated threads.
3. Black glass, very fine and transparent; Iceland agate; lapis obsidianus of the ancients.

D I V I S I O N III.

Mixed Earths and Stones.

THE characteristics of the stones of this division are easily distinguished. We can discover, merely by inspection, of what different matters they consist; and the more readily if we compare them with the stones of the two foregoing divisions. We formerly observed, that, in order to analyze them, it is first necessary to divide the various substances with an hammer; after this operation is performed, they are found to consist of simple united with compound stones. If these mixed stones be exposed unbroken to the action of fire, they will melt with more or less facility into a party-coloured glass, the nature and colours of which will be according to those of the matters of which it is composed.

These stones appear to have been formed by the union of the several substances of which they consist, effected either by fire or water. On account of this circumstance, Bucquet subdivided this third division into

two orders, as well as the foregoing. His first order comprehends mixed stones formed by water: the second, such as owe their composition to fire. As this subdivision is authorised by many more facts than that of the second division, we shall follow it with more confidence.

ORDER I. EARTHS and STONES Mixed by WATER.

Genus I. *Petro-filix*, or *Rock-Stone*.

By this name naturalists denote a stone of an intermediate hardness between soft stones and filix. M. Daubenton ranks it among the vitreous stones, because it scintillates with steel, and its fracture is vitreous, though sometimes rather scaly. *Petro-filix* has a kind of faint or half transparency like wax. It is dusky and destitute of brilliancy, and has even somewhat of the appearance of tallow; it is fine grained and very compact; it is found in large masses: it sometimes displays layers variously shaded, disposed one over another. The chemical characteristic by which M. Bucquet distinguished it, was its disposition to melt by fire into an opaque glass. It is far from being so easily discoverable to be a mixture as the following genera; it seems to possess the characteristics of compound stones*; and for

* I must here observe, that these characteristics of stones, derived from the manner in which they are affected by fire, are founded on experiments made by M. Bucquet, in conjunction with the Duke de Rochefoucault, in an excellent furnace for fusion, constructed on purpose in the laboratory in which that illustrious cultivator of chemistry

for this reason we rank it at the head of the third division: it forms a kind of intermediate step between this and the foregoing.

The form of its layers, the matters which they often contain, and still more the masses in which it is accumulated in the bowels of the earth, show plainly that it owes its origin to water.

Species.

1. Grey petro-filex.
2. Reddish.
3. Greenish.
4. Brown.
5. Black.
6. Spotted.
7. Veined.

Genus II. Pudding-Stone.

PUDDING-STONE is a mixture of flints united by a cement of a different nature. That cement is either gritty or argillaceous, or ochreous; sometimes it is hard, and resembles filex.

Its formation is by no means equivocal; it is owing to water. These stones are always found either on the sea-shore, or in places which have been once covered with water, and afterwards left dry.

Species.

mistry prosecutes so many researches for the improvement of the science. I have re-examined most of the results of those experiments, which it is to be hoped will be one day communicated to the public: they will confirm the fine series of experiments made by M. D'Arcet; and will add to them a number of facts, serving to support Bucquet's arrangement of stones.

Species.

1. Sandy pudding-stone.
2. Ochreous.
3. Argillaceous.
4. Siliceous.
5. Agatified; susceptible of the finest polish.

Genus III. *Granite.*

GRANITE is formed by the union of smaller or larger fragments of three different stony matters. These are quartz, felt-spar, and mica.

On account of the quartz and feldt-spar which it contains, it gives fire with steel: its fracture is irregular and coarse-grained: it is fusible, but in various degrees, according as the three component matters are proportioned in the composition. It is susceptible of a finer or an inferior polish according to the fineness of its grain and the hardness of its principles. Some species of it suffer alteration, and waste away by the action of the external air. This last phænomenon enables us to distinguish ancient from modern granite. It has been subdivided into many species: But we shall reduce them all to the following *.

VOL. I.

R

Species.

* The natural history of granites has been much studied by modern naturalists. M. Saussure, in his *Voyage des Alpes*, has communicated a number of new and important facts on this head. Granites are not invariably formed of a mixture of those three stones. Some of them, instead of mica, contain schorl; others contain both schorl and mica at the same time. A mixture of quartz and feldt-spar, without a third substance, constitutes *granitine*: quartz and schorl compose *granitello*.

Species.

1. White granite.
2. Grey.
3. Red.
4. Brown.
5. Green.
6. Black.
7. Dirty and friable granite, having suffered alteration by the action of fire.

Genus IV. *Porphyry*.

PORPHYRY is a stone speckled with spots on a ground of red, or some other colour. It produces abundance of sparks when struck with steel.

It differs from granite in being harder and susceptible of a much brighter polish: it seems to consist of feldt-spar and schorl, united by a quartzose cement.

The paste which constitutes the ground of porphyry is of a very fine close grain; the other fragments united in it are generally much less than those of granite. This stone is fusible into a coloured glass. All the species of porphyry may be reduced to the following seven.

Species.

1. Red porphyry, with large spots.
2. Red porphyry, with small spots.
3. Green porphyry, with large spots.
4. Green porphyry, with small spots.

Species.

nibello. See an account of these particulars in *Saunders's Voyage dans les Alpes*. A.

Species.

5. Black porphyry, with large spots.
6. Black porphyry, with small spots.
7. Coarse porphyry, of a dirty red, almost without spots, nearly of the same nature with sand-stone.

Genus V. *Ophites*, or *Serpentine*.

PLINY gave the name of *ophites* to a kind of stones spotted like a serpent's skin. Bucquet considered those as a kind of porphyry, but harder, of a more ancient formation, and having their component parts much more intimately united than the other kinds. They have likewise received the name of *serpentine*, or *hard serpentine*. On comparing this stone with porphyry, it appears that they are both composed of a quartzose paste, with feldt-spar and schorl; but that in serpentine the fragments of feldt-spar and schorl are large and rhomboidal, while in porphyry they are very small.

Serpentine gives fire with steel; its fracture is fine and half scaly; it melts in the fire.

The following are most of the species of serpentine which we have had occasion to see.

Species.

1. Ophites of a deep green ground, with large white spots.
2. Dark green ophites, with oblong spots of a paler green.
3. Ophites resembling the preceding species; its spots very small, and scarcely visible: Many

R. 2

savage

Species.

savage nations use it for money: it has received the name of *thunder-stone*.

4. Brown ophites, with irregular oblong spots of a rose-coloured white.

We are almost entirely ignorant of the circumstances of the formation of ophites. We know not even whether it be owing to fire or water. But as they resemble porphyry, we have for this reason placed them immediately after that genus.

ORDER II. EARTHS and STONES Mixed by FIRE.

Continuation of the Volcanic Products.

THE origin of these substances is well known; they are never found but in the neighbourhood of volcanoes, or in places where volcanic fires have formerly existed. Besides, they possess all the characteristics of products of fire. These, together with the compound stones above described, will form a complete list of volcanic products.

We include not under this name all the matters which are found near volcanoes. Many of them are not altered by fire, such as most of the stones above described, more especially granite, clays, &c. as well as many saline substances, together with calcined, melted, sublimated, and vitrified matters. They exhibit nothing very remarkable, and were we to describe them here, it would occasion an unnecessary repetition. We shall in another place take notice of their existing in the neighbourhood of volcanoes, and of the alterations produced on them by subterraneous fire.

Genus

Genus I. *Volcanic Ashes.*

THE name of *volcanic ashes* has been improperly given to a kind of pulverized earthy matters of various colours, which are found in the neighbourhood of volcanoes. They appear to be composed either of a mixture of substances discharged from the volcano, or of lavas altered by the action of air and water. Bucquet thought them to be combinations of iron and clay. They are generally attracted by the magnet. We know only two species of them.

Species.

1. Rapillo, a pulverized matter, of a blackish grey, which is found round the edges of volcanic craters.

Rapillo contains garnets and schorls, the form of which is still discernible, though their angles have been softened and incruited by some matter in fusion.

2. Puzzolana. This substance has received its name from the town of Puzzoli, where it has been made use of since a very remote period: it is an argillaceous earth impregnated with iron, and variously coloured according as it contains a greater or a less proportion of the metal. There is grey, black, yellow, red, and brown puzzolana. It melts by fire into a black enamel. It is used to compose a kind of cement or mortar, which possesses the property of becoming hard in water. M. Faujas de St Fond found some of it in Vivarais. He thinks that it is formed by the alteration and attrition of porous lavas, and even of basalt. That philosopher, in his researches on the nature of puzzolana, gives

an account of the processes necessary for building with it, both under water, and where it is to be exposed only to the action of the air.

Genus II. *Lavas.*

THIS name is given to matters which have been melted and half vitrified by volcanoes. They are usually scattered over the sides of mountains, the interior parts of which are inflamed with volcanic foci. They issue from the craters of volcanoes in burning streams, which sometimes overflow a wide extent of country, carrying destruction and desolation wherever they direct their course. So considerable is their bulk, and so intense their heat, that they cool but very slowly, and are not quite cold till after several years. In cooling, they crack and separate into masses, which are sometimes of a regular form: and this seems to be the origin of basaltes. In cabinets of minerals there is a great variety of these stones. They generally consist of a grey paste, of a lighter or a deeper shade; in grain and hardness subject to great varieties; with crystals or irregular fragments of schorl, garnet, glass, zeolite, &c. interspersed; which makes a true mixture. It is impossible to point out any certain general properties of lavas; for they all differ from one another in grain, cohesion, hardness, colour, composition, &c. They are all in general very fusible, and afford a kind of blackish enamel, like volcanic glass. M. Cadet found them to contain iron, copper, and siliceous and aluminous earth. Bergman believed them to consist of siliceous, aluminous, and calcareous earths, with a mixture of iron. Many lavas, and more particularly those

those which are most compact, possess the property of acting upon the magnetic needle.

Species.

1. Soft lava of various colours, containing crystals of black schorl.
2. Soft lava of various colours, containing crystals of green schorl.
3. Soft lava, of various colours, with crystals of white schorl.
4. Reddish lava, with blackish crystals.
5. Yellowish saline lava.
6. Soft lava, with garnet crystals.
7. Porous lava, of a gentle lustre (*Fr. Chatoyant.*)
8. Porous grey lava; volvic stone.
9. Soft blackish lava, with white crystals.
10. Grey lava, somewhat compact, with duodecahædral, opaque crystals, or garnets altered by fire.
11. Ancient lava, very compact, of a blackish grey, and speckled with spots of a deeper colour.

Genus III. *Basaltes.*

THERE is nothing more inaccurate in the writings of naturalists than their descriptions of basaltes. Some have confounded both schorls and garnets with this substance. There is no where to be found an accurate definition of the word *basaltes*. Some consider them as products of volcanoes; others think them to be formed by water. The experiments and observations

of Messieurs Desmarets and Faujas de St Fond, induce us to prefer the former of these opinions. Regularity of form, absolute opacity, and a considerable degree of hardness, such as that it gives fire with steel, a grey ashy colour, and an evident mixture of schorls, or small fragments of vitrified matter, of a deeper colour than the mass through which they are interspersed, may be considered as the distinctive characteristics of basaltes. They are likewise fusible.

Among this genus there are stones of enormous bulk, and collected in vast masses, which appear to have been formed at some very remote period in antiquity. Such are, 1. The columns of the Giant's Causey in the county of Antrim in Ireland. 2. The rock of Pereneire near St Sandoux in Auvergne, which is very accurately described by M. Desmarets. There are others regularly crystallized in small prisms of three, four, or five faces, &c.: their form, size, and disposition, are extremely various.

They are usually arranged in regular order, one beside another. No analysis of them has yet been made from which any thing could be determined concerning their nature. They seem to be nothing but lavas apparently crystallized, in consequence of the cracks which run through them in all directions while they are cooling *. Their arrangement and amazing varieties

* One theory which has been received concerning the formation of basaltes, is, that when a stream of lava pours into the sea, the impulse of the water causes it to contract and split into regular figures. But the ingenious M. Houel, in his *Voyage Pittoresque*, &c. shows this theory to be inconsistent with facts. He proposes another, in which he ascribes the formation of basaltic columns to the heterogeneity of the matters of which lavas are composed. An ingenious theory! but not sufficiently confirmed by facts.

rieties give considerable weight to this opinion: it likewise appears, that water insinuating itself into the chinks, deposites in them different kinds of earth, and alters the corresponding sides of the basaltic columns: and this seems to be the cause that produces the yellow or brown crusts with which they are covered.

Species.

1. Basaltes in very long polygon prisms, not terminating in regular pyramids.
2. Basaltes in short truncated prisms, of three, four, five, or seven faces.
3. Basaltes in short polygon prisms, terminating on the upper end in a concavity, at the lower in a convexity; articulated basaltes.
4. Small basaltes, quadrangular, triangular, &c.; formed by the fracture of the larger columns, and united in the same group with them *.

Genus IV. *Scoriæ of Lavas.*

The melted matter of which lavas consist is a mixture of various heterogeneous substances, differing in density and gravity. As it is slowly cooled, those several substances are separated, according to their gravities. Hence the scoriæ of lavas. These are spongy sub-

* For the history of these stones, and all the other products of volcanoes, see an excellent work intituled *Mineralogie des Volcans, par M. Faujas de St Fond, Paris, 1784.* F.

substances which have not been so thoroughly melted as the lava, and whose levity raises them to the surface of the mass. In other respects they appear to be of the same nature with lava; the only difference being, that they are a more imperfect mixture. Scoriæ, as well as lavas, are found to contain schorl and garnet crystals.

Species.

1. Ponderous volcanic scoriæ, of a compact texture.
2. Black cellular volcanic scoriæ.
3. Black spongy volcanic scoriæ.
4. Black volcanic scoriæ, twisted like a rope.
5. Yellow ochreous volcanic scoriæ.
6. Reddish volcanic scoriæ.

The two last species plainly appear to have suffered alteration from the contact of air, water, and acid vapours.

Such was the classification of earths and stones which Bucquet thought proper to adopt in the years 1777 and 1778. Great progress has since been made in the chemistry of mineralogy. Stones are now analysed in almost every laboratory. Messrs Bayen, D'Arcey, Monret, de Morveau, Sage, Mongez, and Pelletier, in France; Scheele and Bergman in Sweden; Achard, Bindheim, and Hupfch, at Berlin; de Saussure in Switzerland; Woulfe, Withering, and Kirwan, in England, have examined a great number of earths and stones: and in consequence of those analyses, the classification of earths and stones must undergo a considerable change. Two of those chemists have

there.

therefore published new systems of mineralogy, in which their arrangements are founded on the nature of the component principles of minerals. But their methods are totally different from that of Bucquet, who sought to associate exterior characteristics with chemical properties. Bergman and Kirwan have paid no regard to physical qualities; the nature, the quantity, and the proportion of the component principles are the particulars on which they found their arrangements. Their system, though it may contribute greatly to the advancement of chemical knowledge, cannot teach us to distinguish stones by their appearance and sensible properties. It was therefore absolutely necessary to give, as we have done, some physical method, before entering on the examination of these systems. The one throws light on the other; and they may thus be equally useful to the student of mineralogy.

§ II. BERGMAN'S *Chemical arrangement of Earths and Stones* *.

BERGMAN, after showing that external properties, if judiciously selected, may be of use in forming a classification of minerals, but are not of themselves
fully

* This section is an extract from Bergman's work, published in French, by M. Mongez, under the title of *The Mineralogist's Manual*, &c. F.—There is an English translation of it by Dr Withering.

fully adequate to that purpose, establishes his principal divisions of classes and genera on the composition and intimate qualities of those bodies. Every mineral is arranged by that principle which is the most powerful, or the most copious in its composition: all minerals, or fossils, are in this system divided into four classes; salts, earths, bitumens, and metals. We shall here take notice of none but the earths.

Bergman acknowledges five different kinds of simple earth; terra ponderosa, lime, magnesia, clay, and filiceous earth *.

He first examines each of these as pure earths, tho' none of them is ever found such in nature: he observes, that these five earths combine into twenty different species, ten of two, six of three, three of four, and one of the whole five. But he ranges among the species of earths all such of their combinations with acids as are not soluble in one thousand times their own weight of boiling water; and those species are thus increased to a vast number. Besides, two compound earths, though made up of the same component principles, may differ widely as to the proportion in which those principles exist in them; even so much as to be essentially different in their nature. These are the grounds on which Bergman and his commentator the Abbé Mongez, have distinguished earths into different spe-

* Three of these five kinds of earth appear plainly to possess saline properties, namely, *barytes* or ponderous earth, magnesia, and lime; and we therefore reserve the history of them to the second part of the work. Bergman, whose intention was to divide stones according to their principles, was obliged to rank them among the earths, because they are often united with each other. Many of the substances which that illustrious chemist has placed among stones, come in our method to be considered as salts. F.

species; for Mongez has made considerable additions to the labours of the Swedish chemist. The following are the species into which they divide each of the primary earths.

Ponderous Earth *.

Species.

- I. Pure ponderous earth. This is nowhere to be found in nature; it is obtained, as we shall afterwards see, by decomposing ponderous spar.
- II. Aerated ponderous earth; a combination of terra ponderosa with the aerial acid. This compound has not hitherto been found in nature: Bergman thinks that it may exist in water in a state of solution †.
- III. Vitriolated ponderous earth; ponderous spar: a combination of ponderous earth with the vitriolic acid. Abundance of this substance is found in mines. The Bologna stone is a variety of it.
- IV. Vitriolated ponderous earth, containing petroleum, mixed with selenite, alum, and siliceous earth; the hepatic stone of Cronstedt. This is a bright yellow, brown, or black spar

* We shall here follow the denominations of Bergman. It will be easy to refer the ancient names both of earthy bases and of the acids united with them, to the new and methodical denominations which we shall give those bodies in the history of saline matters. See the end of this volume, and the second. A.

† A natural compound precisely of this species has been found in England since the death of Bergman. See the extract from Kirwan's Mineralogy. A.

sparry substance; strong smelling, and not effervescent with acids. A quintal of this natural compound contains, according to Bergman, 33 parts of siliceous earth, 29 of pure terra ponderosa, and 5 of clay, besides lime, water, and vitriolic acid.

Lime.

Species.

I. Pure or quick-lime. Bergman knew not whether this substance existed in nature.

II. Aerated lime; chalk, or calcareous earth; a combination of lime with the aerial acid. It often contains marine salt of magnesia, calcareous marine salt, clay, and siliceous earth or iron. In the bowels, or on the surface of the earth, it constitutes lac luna, congelations, calcareous stones, marbles, calcareous spars, concretions or stalactites, &c.

III. Bituminous aerated lime, or lime impregnated with petroleum; swine-stone. It is found in France at Villers-Cotterets, Plombieres, and Ingrande in Anjou; at Rattwik in Dalecarlia, Kinekulle in Westrogothia, Krafnaselo in Ingermania, in Portugal, in Sweden, &c. If violently rubbed, or heated, it diffuses a fætid smell, which sometimes affects the nostrils in the same manner with cat's urine; and some authors have therefore given it the name of *lapis felinus*. It effervesces with acids, decrepitates, and loses its smell and colour in fire. When distilled in large quantities, it affords, 1. A

Species.

fetid liquor, which turns the syrup of violets green, and effervesces with acids; 2. A blackish oil, of a strong smell, resembling that which is obtained from pit-coal; 3. Concrete volatile alkali. The residue contains a little marine salt. This substance owes its peculiar properties to the bitumen mixed with it.

IV. Fluorated lime; fluor mineral, or vitreous spar. A combination of lime with the spathose or fluoric acid, with a mixture of clay and siliceous earth, and a little of the marine acid.

V. Lime saturated with a peculiar acid, probably metallic *; ponderous stone; Swedish *Tungsten*. This is the weightiest of all stones. It is found in small yellow or red grains in the mines of Bastnaes, near Ritterhute in Westmania; at Marienburgh and Altenburgh in Saxony, it is sparry, bright, and whitish. It is often confounded with white tin ore. It scarce yields to the action of fire, and is vitrifiable only at the surface: it is not soluble in boiling water; the vitriolic acid separates the lime: by dissolving it in volatile alkali, precipitated by the nitrous acid, a white powder is obtained, which is the peculiar acid discovered by Scheele. In order to recognize and distinguish

* Found to be so. See Scheele's Essays, and De Luyart's on Wolfram, both translated into English.

Species.

guish it from other stones, we must first reduce it to powder, and then pour upon it a due quantity of the nitrous or of the marine acid. This mixture, when gently heated, assumes a fine yellow colour. (See *Le Journal de Physique*, 1783, tome 22.

VI. Aerated lime, contaminated * with a small mixture of muriatic magnesia, or marine salt of magnesia.

VII. Aerated lime, contaminated with clay; false marl.

VIII. Aerated lime, contaminated with siliceous earth. Some hewing stones and marbles give fire with steel, on account of the fragments of flint or quartz which they contain.

IX. Aerated lime, contaminated with a mixture of argillaceous and siliceous earth; perfect; marl.

X. Aerated lime, contaminated with iron and manganese: false white iron ore; black and dusty, or hard, red, or whitish. The mines of Hallefors exhibit these varieties †.

Magnesia.

I. Pure magnesia. This is always a product of art.

II. Aerated

* The word contaminated, *inquinatus*, is used by Bergman to denote the mixture of two or more earths, when no real combination takes place. We shall therefore sometimes substitute the word *mixed* in its place. A.

† All these species are saline substances, which will be described in the history of salts.

Species.

II. Aerated magnesia, dissolved in water saturated with aerial acid.

III. Aerated magnesia, mixed with filiceous earth. It scintillates and effervesces.

IV. Magnesia, intimately combined with clay and filiceous earth; steatites, Briançon chalk, soap-stone, lapis ollaris, serpentine, lapis nephriticus.

V. Magnesia, combined with a considerable portion of filiceous earth, and a smaller quantity of calcareous and argillaceous earth, and contaminated with calx of iron. Asbestos; mountain cork; mountain leather; amianthus. Bergman found a quintal of amianthus to contain 64 parts of filiceous earth, $18\frac{1}{2}$ ths of magnesia, $6\frac{2}{3}$ ths of lime, 6 of vitriolated ponderous earth, $3\frac{1}{10}$ ths of clay, and $1\frac{1}{4}$ th calx of iron; a quintal of asbestos afforded 67 parts of filiceous earth, $16\frac{1}{4}$ ths of magnesia, 6 of clay, 6 of lime, $4\frac{1}{4}$ th of calx of iron.

VI. Magnesia mixed with argillaceous and filiceous earth, and with pyrites; a kind of ore of alum described and analysed by M. Monnet, (*Syst. de Minerologie, genre 9. page 161.*)

VII. Magnesia mixed with argillaceous and filiceous earth, pyrites, and petroleum; magnesian aluminous schistus.

Clay.

I. Pure clay. It is precipitated from alum by aerated volatile alkali.

II. Clay mixed with filiceous earth. Porcelain earth;

Species.

earth; Chinese kaolin. Solid clay from Saint-Iriez in Limousin, from Japan, and from Saxony. Pulverulent clay from Westmania, Boherap, and China. These earths are often mixed with mica. Clays for potteries and delft-ware are coarser, but of a similar nature.

III. Clay mixed with iron and siliceous earth. Boles or bolar earth, grey, yellow, red, brown, and black. These, when washed, become *terræ figillatæ*. Common clays, of a green, blue, or red colour, are of this species.

IV. Clay mixed with siliceous and calcareous earths. Argillaceous marl; pipe clay; agarie mineral or fossil.

V. Clay mixed with siliceous and magnesian earth. Lemnian earth; fuller's earth; soap-stone; *smectites*. Bergman obtained from Lemnian earth, Hampshire clay, and English fuller's earth, a considerable quantity of siliceous earth, about $\frac{3}{4}$ th of clay, and as much aerated lime, with $\frac{1}{8}$ th of aerated magnesia, and the same quantity of oxide of iron. He gives to these earths the generic name of *lithomarga*.

VI. Clay contaminated with sulphur and vegetable alkali: alum ore of Tolfa and Solfaterra. Bergman takes it to be a volcanic product.

VII. Clay mixed with siliceous earth, pyrites, and petroleum; aluminous schistus. It is found in Italy, in the district of Liege, in Sweden, and in Jemteland. Black crayons, such as those from Bechel, near Seez in Normandy, and

Species.

and the ampelites, are of this species. Tripolis are of the species of aluminous schisti, more or less burnt. Such are those of Poligné in Normandy and of Menat in Auvergne.

M. Mongez comprehends under this species those schisti which contain much clay, and more or less siliceous earth and bitumen. Most of them contain likewise a mixture of calcareous earth, and effervesce with acids. The proportions in which the component principles are mixed in these schisti are extremely various. Some of them are so bituminous, that they burn with flame; others are full of pyrites, and effervesce in the air; some again are excessively hard, and give fire with steel. M. Mongez admits five varieties: 1. Hard argillaceous schistus, or writing slate: 2. Soft argillaceous schistus, or slate for roofing houses: 3. Soft siliceous schistus, used in polishing metals: 4. Hard siliceous schistus, used for whetting razors; scythe-stone: 5. Hard calcareous schistus, which makes an indifferent lime, such as that of Allevard in Dauphiny.

VIII. Clay combined with nearly half its weight of siliceous earth, a little aerated lime, and some oxide of iron; crystal gems. Bergman's fine discoveries concerning the nature of crystal gems, which, from their excessive hardness and apparent inalterability, were formerly thought not to be susceptible of a chemical analysis, have been

Species.

confirmed by the experiments of Messrs Margraf, Gerhard, and Achard. The following is the result of Bergman's analysis of the five crystal gems, which are varieties of the species we are now considering.

	Clay.	Silic.	Lime.	Iron.	} 100th parts.
Oriental emerald contains	60	24	8	6	
Oriental sapphire	58	35	5	2	
Saxon topaz	46	39	8	6	
Oriental hyacinth	40	25	20	13	
Oriental ruby	40	39	9	10	

The means employed by this ingenious chemist for resolving stones into their component principles, though very ingenious are very simple. (See *le Journal de Physique*, 1779, tome 14. p. 268 ; tome 21. p. 5 et 101) *.

IX. Clay combined with a portion of filiceous earth, equal to more than half the weight of the whole mass, with a very small quantity of aerated lime and some iron ; garnet, schorl, tourmalin. In these stones the proportion of the iron varies. (See the analysis of the Tourmalin of Tyrol, by M. Muller, *Journal de Physique*, tome 15. p. 182. ann. 1780).

X. Clay slightly combined with half the weight of the mass, or rather more, of filiceous earth, and a small quantity of lime ; zeolite. M. Mongez considers the azure stone, *lapis lazuli*, as a zeolite. M. Margraaf found a small

* Or rather Bergman's Essays.

Species.
small quantity of gypsum, ready formed, in the *lapis*.

XI. Clay combined with a considerable quantity of siliceous earth and a little magnesia; talc, mica. The proportion in which the principles exist in this stone is not yet perfectly determined.

Genus V. *Siliceous Earth*.

I. Pure siliceous earth. This is obtained by melting white quartz with four parts of fixed alkali, dissolving the whole in distilled water, and precipitating the earth with an acid. The precipitated earth is then washed and thoroughly dried.

II. Siliceous, united with a very small proportion of argillaceous and calcareous earth: The several varieties of rock-crystal, of quartz, and of grit-stone.

III. Siliceous, united with argillaceous earth. Hydrophanes chalcedony or *oculus mundi*: according to M. Gerhard of Berlin, this stone contains a greater quantity of clay than of siliceous earth. Opal: M. Mongez considers cat's eye, fish's eye, and girasol, as varieties of this stone. To these three he adds agate and its varieties; cacholong, cornaline, sardonyx, gun-flint, and jade. They have not as yet been analysed with sufficient accuracy.

Species.

IV. Siliceous earth united with clay strongly impregnated with iron; jasper. M. Mongez considers the finople as a variety of the jasper.

V. Siliceous earth united with such a quantity of martial earth as renders it ponderous; false jasper. M. Mongez calls this stone a metallic quartz. He distinguishes it into the black coloured by iron, and the red coloured by copper.

VI. Siliceous united with argillaceous earth, and a little lime; petrosilex. This stone sometimes gives fire with steel, and effervesces with acids. It melts in a strong fire.

VII. Siliceous earth united with clay, and a little magnesia; feldt-spar. It suffers a change of colour, and melts in the fire. Air does not decompose it. It gives fire with steel, and breaks at every stroke.

VIII. Siliceous earth united with magnesia, aerated and fluorated lime, and a portion of oxide of copper and iron; prase, chryso-prase. Bergman gives the composition of this stone from an analysis of it by M. Achard.

I. APPENDIX.

BERGMAN, in his first appendix, treats of mineral substances mechanically mixed or united, in such a manner

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ner that the principles of the mixture or composition may be at once distinguished by ocular observation. We shall mention none but mixtures of earths; such are the stones known by the name of rocks, *saxa*. M. Mongez, who has made considerable additions to what Bergman had done on this head, distinguishes these stones or rocks into two genera. 1. The first, those whose parts are not united by any cement, but simply adhere by juxtaposition. These are formed by the agglutination of a number of fragments. He distinguishes them into three species,—granite, gneis of Saxony, and horn-stone. 2. His second genus comprehends such mixed stones as have their parts incrustated in a common cement; as is the case with the four species of porphyry, ophites or serpentine, breccia, and pudding-stone. We shall here give the varieties of these stones acknowledged by this naturalist.

I. GRANITE is a composition formed by the union of quartz, feldt-spar, mica, schorl, and steatites, mixed in various proportions; consisting sometimes of two of these substances, sometimes of three, and sometimes of four. Quartz is always the base.

Variety I. Granite of two substances; granitin.

A. Quartz and feldt-spar.

B. Quartz and schorl.

C. Quartz and mica.

D. Quartz and steatites.

Variety II. Granite of three substances.

A. Quartz, feldt-spar, and mica. This is the most common, the most plentiful, and the most varied of all.

B. Quartz, mica, and schorl.

C. Quartz, schorl, and steatites.

Variety III. Granite of four substances.

A. Quartz, feldt-spar, schorl, and mica.

B. Quartz, feldt-spar, schorl, and steatites.

II. GNEIS is a mixture of quartz in grains, and mica in a greater or a less proportion, with a considerable quantity of clay or steatites, which constitutes the base of the stone. This stone is foliated like the schistus. Exposure to the air soon alters and wastes it down, because the clay absorbs the moisture. Many varieties of the gneis are found on the Alps of Dauphiny.

III. HORN-ROCK is a compact stone, consisting of very minute particles of an earthy aspect, and exhibiting over its surface sparkling points of mica. When moistened or struck, it diffuses a clayey smell. It hardens in the fire like clays, and when exposed to a very strong heat, melts into a blackish scoria or a black glass. Its colours are extremely various. M. Mongez thinks the Swedish *trapp* a variety of the horn-stone.

IV. PORPHYRY seems to be composed of a fine hard paste, of the same nature with red jasper, containing either irregular or crystalline grains of quartz, white or reddish feldt-spar, and sometimes of green or black schorl.

V. OPHITES, or serpentine, is a species of porphyry, of a green paste, and greenish white spots. The spots of the ophites are generally oblong; whereas those of porphyry are square or rhomboidal. The thunder-stone is a variety of this species.

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VI. BRECCIA, from the Italian word *briccia*, a crumb or fragment. This is a mixed stone of a much later formation than any of the above, formed of the ruins of the primary mountains, of irregular worn pieces of filix, &c. united by a common cement. M. Mongez makes no specific distinction between breccias and pudding-stones; but gives to the latter a compound name, indicating the nature both of their fragments and of their cement. He distinguishes these stones into eight varieties: The calcareo-calcareous breccia, under which denomination both the breccia properly so called and the lumachello are included; the filiceo-filiceous breccia, or the pudding-stone*; the breccia consisting of calcareous and filiceous fragments, with a calcareous cement; the breccia with filiceous cement, and fragments of the calcareous and filiceous genus; the arenario-filiceous breccia,—of this variety is the grey stone of Chartres; the breccia with a cement and fragments of jasper; the breccia with a cement and fragments of porphyry; and the volcanic breccia.

II. APPENDIX.

Volcanic Products.

M. MONGEZ, with Bergman, divides volcanic products into such as are formed by fire, and such as owe their

* According to this nomenclature, the first of the two names affixed to the breccia expresses the nature of its cement; the second, that of its fragments.

their origin to water. The last are nothing but earthy matters, which having been dissolved or suspended in water, are by it deposited in places adjacent to volcanoes, and among their products: of this kind are the calcareous and filiceous incrustations, as well as the zeolites which are often found among volcanized substances.

M. Mongez divides the genuine products of volcanoes into three orders: 1. Earthy substances, but little altered by fire; such as calcareous matters, clays, garnets, hyacinths, schorls, and mica. 2. Earthy substances which have been burnt and calcined; such as volcanic ashes or rapillo, and puzzolana, the tufa, the peperino of the Italians, pumice-stone, and the white earth which covers solfatara. 3. Earthy substances which have been in a state of fusion, or lavas; and of these he admits several kinds,—the spongy lava, the compact lava, the lava in stalactites, and volcanic glasses. After these divisions, he mentions such earthy volcanic products as are of an uncertain origin. Under this order he reckons particularly volcanic schorls, and still more basaltés, which he takes to be masses of trapp softened by the humid vapours of volcanoes, and slowly dried after these have ceased to exhale.

§ III.

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§ III. *Chemical Classification of Earths and Stones, by*
Mr KIRWAN.

IN the year 1784, Mr Kirwan, a celebrated chemist of London, published a work on mineralogy; in which he gives a general classification of minerals, founded on their chemical properties or combinations. The first part of his work contains earths and stones. He gives insipidity, dryness, fragility, incombustibility, and insolubility, as the characteristic properties of these substances. With Bergman, he distinguishes five genera of simple earths,—calcareous earth, ponderous earth or barytes, magnesia or muriatic earth, argillaceous earth, and siliceous earth. From a chemical analysis, he arranges all known earths and stones under these five genera.

CALCAREOUS GENUS.

To this he refers twelve species.

Species.

I. Calcareous earth, not combined with any acid; virgin lime of volcanoes. *Falconer on Bath Waters*, vol. i. p. 156, 157; *Monnet. Mineral. p. 515.*

II. Calcareous earth, combined with aerial acid. Its varieties, which he arranges in
two

Species.

two series, are transparent calcareous spar, opaque spar, stalactites, tophi, incrustations, petrifications, agaric mineral or ghur, chalk, limestone, and marbles. *Bayen, Journal de Physique, tome ii. p. 496.*

III. Calcareous earth combined with the vitriolic acid, gypsum, selenite, or plaster*. He admits two series; the transparent and the opaque.

IV. Calcareous combined with the sparry acid, fluor spar, petuntze of Margraf. Series I. Transparent fluor spars: II. Opaque fluor spars.

V. Calcareous earth combined with the acid of tungsten. Tungsten or ponderous stone. *Woulfe, Phil. Transf. 1779, p. 26.; Scheele's Essays.*

VI. Aerated calcareous earth, mixed with a discernible quantity of magnesia. Var. I. Compound spar, described by *Mr Woulfe, Phil. Transf. 1779, p. 29.* II. Creutzwald stone, analysed by *M. Bayen†, Jour. de Phys. tome xiii. p. 59.*

VII. Aerated calcareous earth, mixed with a discernible quantity of clay. Var. I. Calcareous marl. II. Travertino, margodes, stony

* Mr Kirwan classes many earthy salts among stones; though they be even one half more soluble than the most soluble stones. A.

† It would be superfluous to give here the proportions in which the several principles are united in these stones, as we will have occasion to mention them in the chemical history of salts. We shall give the proportions only in Mr Kirwan's two last genera, which we consider as genuine earths. A,

Species.

stony marl. *Ferber's Travels in Italy*,
p. 117, 119.

VIII. Aerated calcareous earth, mixed with a discernible quantity of ponderous earth; barytic marl of Derbyshire.

IX. Aerated calcareous earth, mixed with a discernible portion of siliceous earth. Var. I. Stellated spar. II. Calcareous grit; hard free-stone, *Moilon*. *Monnet, Mineralogy*, p. 116.

X. Aerated calcareous earth, mixed with a small quantity of petroleum. Swine-stone.

XI. Aerated calcareous earth, mixed with a discernible quantity of pyrites; *pietre de St. Ambroix*, analysed by the *Baron de Servieres*, *Journ. de Phys. tome xxi. p. 394*.

XII. Calcareous earth, mixed with a discernible portion of iron. Var. I. Aerated calcareous earth impregnated with iron, *Rinman*, *Mem. de Stock. 1754*. II. Tungsten impregnated with iron, *Gronstedt, Mem. de Stock. 1751*.

To these twelve species of calcareous earth, Mr Kirwan adds six species of compound stones, in which calcareous earth predominates. 1. Mixtures of the simple calcareous species, such as selenite and chalk, vitreous spar and tungsten. 2. Compounds made up of the calcareous and barytic species. Of this kind is a yellow stone of Derbyshire, formed of chalk with small lumps of ponderous spar. 3. Compounds of the calcareous and magnesian species; white marble mixed with steatites, the *pietra telchina*, and the *verde antico*.

antico. 4. Compounds of the calcareous and the argillaceous species, of chalk and schistus; such as the green campan of the Pyrenees, the red campan, Florence marble, the griotte, the amandula, the cipolin of Rome (see Bayen, *Journ. de Physique*, tome xi. p. 499. 801, et tome xii. p. 51, 56, et 57.); of chalk and mica, as the cipolin marble of Autun, the macigno, the pietra bigia, and the columbina or turchina of the Italians. 5. Compounds of the calcareous and the filiceous species; scintillating marbles, marble with a mixture of lava. 6. Lastly, compounds of calcareous earth, with two or more of the other genera; such as calcareous porphyry, and the lime-stone mixed with mica.

BARYTIC GENUS.

Under this genus he reckons six species.

Species.

I. Ponderous earth combined with the aerial acid.

A stone found by Dr Withering on Alston Moor in Cumberland.

II. Barytes combined with the vitriolic acid. Ponderous spar.

III. Barytes combined with the spathose acid. This substance exists not in nature, but is a product of art.

IV. Barytes combined with the acid of tungsten. This is obtained in the same manner as the preceding.

V. Aerated barytes, mixed with a discernible quantity of flint and iron. Bindheim.

Species.

VI. Ponderous spar, mixed with filex, mineral oil, and earthy salts. Hepatic stone, white, grey, yellow, brown, or black.

MURIATIC OR MAGNESIAN GENUS.

Mr Kirwan reckons eight species of this genus, arranging under it both those earths and stones in which magnesia predominates, and those which, though containing more filex than magnesia, yet exhibit all the characteristics of the magnesian genus.

Species.

I. Magnesia combined with the aerial acid, and mixed with other earths. Var. I. Mixed with filex; *spuma maris*. The Turkish tobacco-pipes, and the Canadian pipe, are composed of this substance. II. Mixed with calcareous earth and iron; olive-coloured and bluish earth near Thionville. III. Mixed with clay, talc, and iron; greenish yellow Silesian earth.

II. Magnesia combined with the aerial acid, with above four times its weight of filex, and a small proportion of clay. Var. I. Steatites. II. Lapis ollaris.

III. Aerated magnesia combined with filex, calcareous earth, and a small proportion of clay and iron. Var. I. Fibrous asbestos. II. Coriaceous asbestos; mountain cork.

IV. Aerated magnesia, combined with filex, aerated

Species.

ted calcareous earth, barytes, clay, and iron.
Amianthus.

V. Pure magnesia, combined with a quantity of
filex more than equal to its own weight, a
third part of clay, nearly a third of water,
and one or two tenths of iron. Serpentine,
lapis nephriticus, Italian gabro.

VI. Pure magnesia, combined with twice as much
filex, and less than an equal quantity of
clay. Venetian talc, Muscovy talc.

VII. Magnesia combined with the sparry acid.
This substance is not found in nature.

VIII. Magnesia combined with the acid of tung-
sten. This substance is not known to exist
in nature.

To these eight species, Mr Kirwan adds five others,
compounds in which magnesia predominates. 1. Com-
pounds of the several species of magnesia with one ano-
ther; steatites and talc, Briançon chalk; serpentine
with steatites or asbestos. 2. Compounds of the mag-
nesian with the calcareous species; red or yellow ser-
pentine, with spots of white calcareous spar, *potzovera*;
the black is the *Nero di prato*, and the green the *verde
di suza* of the Italians. 3. Compounds of the magne-
sian and the barytic species; serpentines with spots or
veins of ponderous spar. 4. Compounds of the mag-
nesian and the argillaceous species; steatites mixed
with clay, mica, or schistus. 5. Compounds of the
magnesian with the siliceous species; serpentine veined
with quartz, feldt-spar, or schorl.

ARGIL-

ARGILLACEOUS GENUS.

Mr Kirwan reckons fourteen species of this genus.

Species.

- I. Clay saturated with the aerial acid; *lac lunæ*, according to Schreber's analysis.
- II. Clay combined with the aerial acid, and mixed with filex and water; potter's clay, pipe and porcelain clay, &c.
- III. Clay saturated with the vitriolic acid; embryo alum in scales like mica *Baumé*.
- IV. Clay saturated with the marine acid; marine embryo alum.
- V. Clay combined with about one part and an half of filex, nearly one part of magnesia, and half a part of dephlogisticated iron; mica.
- VI. VII. VIII. IX. Clay combined with filiceous earth, magnesia, calcareous earth, iron, or a bitumen; slate, blue schistus, pyritous schistus, bituminous schistus, and argillaceous schistus.
- X. Clay combined with a little filex, magnesia, and calcareous earth, with a quantity of iron calx, nearly equal in weight to the clay; hornstone, or *horn-blende*.
- XI. Clay combined with a quantity of filex equal to four times its own weight, with half its weight of calcareous earth, and somewhat more than its weight of iron; toadstone.
- XII. Clay united to from twice to eight times its own weight of filex, half its weight of lime,

Species.

and once or twice its weight of water; zeolite.

XIII. Clay united with four times its own weight of filex, and one third of iron; pitch-stone, lava.

XIV. Clay mixed with a discernible portion of red iron calx, and sometimes with steatites; red chalk.

To these Mr Kirwan adds six compound species in which the argillaceous genus predominates.

SILICEOUS GENUS.

This genus, in Mr Kirwan's system, comprehends twenty-six species.

Species.

I. Siliceous earth nearly pure; quartz, crystal, sand.

II. Siliceous earth, with one-fourth clay, and one-fortieth calcareous earth; filex, gun flint.
See *Wiegleb. Act. nat. Curios. t. 6. p. 408.*

III. Siliceous earth, with from one-fourth to one-third clay, and from one-twelfth to one-fifteenth calcareous earth; petrofilex.

IV. Siliceous earth, with one-third clay, and one-sixth or one-seventh iron calx; jasper.

V. Fine siliceous earth, mixed in various proportions

Species.

tions with iron and other earths; agate, opal, chalcedony, onyx, cornaline, and sardonyx. Precious stones of the second order.

VI. Siliceous earth, with from an equal quantity to nearly three times its own weight of clay, from a sixth part to an equal quantity of calcareous earth, and from one-eighteenth to an equal quantity of iron; ruby, topaz, hyacinth, emerald, sapphire. Precious stones of the first order.

VII. Amethyst. The principles of its composition are not yet known.

VIII. Siliceous earth, with one fifty-fifth of calcareous earth, a smaller quantity of magnesia, and a very small quantity of iron, copper, and sparry acid; chrysoprase.

IX. Siliceous earth, with blue fluor spar, and a little gypsum; *lapis lazuli*. M. Margraf found in it chalk, gypsum, filex, and iron. M. Rinman observed it to contain a portion of the sparry acid.

X. Jade. M. Kirwan conjectures it to consist of filex, magnesia, and iron.

XI. Siliceous earth, with clay, ponderous earth, and magnesia; feldt-spar, petuntze, and Labrador stone. 100 parts of feldt-spar contain 67 parts of filex, 14 of clay, 11 of ponderous earth, and 8 of magnesia.

XII. Siliceous zeolite. This substance is found at Mæssiberg. It differs from the true zeolite in giving fire with steel, which the other

Species.

does not; and this property is a proof that filex is one of its principles.

XIII. Siliceous earth, with clay equal to more than a third part of its weight, and one-ninth of chalk, with no iron; white garnet of Mount Vesuvius. 100 parts of it contain, according to Bergman, 55 of filex, 39 of clay, and 6 of chalk.

XIV. Siliceous earth with clay, chalk, and one-tenth of iron; garnet. Bergman says that 100 parts of this stone contain 48 of filex, 30 of clay, 12 of calcareous earth, and 10 of iron.

XV. Siliceous earth, with a good deal of clay, nearly one-tenth of chalk, and a little iron and magnesia; schorl.

XVI. Bar schorl, German *Stangen sjoerl*; found by M. Fichtel on the Carpathian mountains. It is found among lime-stone, is of a prismatic form, and gives a slight effervescence with acids. M. Bindheim obtained from 100 parts of this schorl, 61 of filex, 21 of chalk, 6 of clay, 5 of magnesia, 1 of iron, and 3 of water.

XVII. Tourmalin. The following are, according to Bergman, the proportions of the principles of the tourmalins of Tyrol, Ceylon, and Brazil.

	Clay.	Sil.	Cal.	E.	Iron.	
Tourmalin of Tyrol	42	40	12	6	} 100th parts	
———— of Ceylon	39	37	15	9		
———— of Brazil	50	34	11	5		

Species.

XVIII. Basaltes, trapp. 100 parts contain, according to Bergman, 52 of filiceous earth, 15 of clay, 8 of calcareous earth, 2 of magnesia, and 15 of iron.

XIX. Rowly rag. A grey granulated stone, which heat renders magnetic and melts, and which in the air acquires an ochreous crust. 100 parts of it, according to Withering, contain 47.5 of filiceous earth, 32.5 of clay, and 20 of iron.

XX. Silex, clay, iron, and calcareous earth, melted together by volcanic fire.

1. Cellular lavas, improperly called pumice-stones. These have been very imperfectly melted. Bergman found them to contain from $\frac{45}{100}$ to $\frac{50}{100}$ of silex, from $\frac{15}{100}$ to $\frac{20}{100}$ of iron, $\frac{4}{100}$ or $\frac{5}{100}$ of pure calcareous earth; and the rest of the composition clay.

2. Compact lavas. These have undergone a second fusion, and have therefore but few cavities. They sound when struck.

3. Vitreous lavas, or lava entirely melted into black, green, blue, &c. glass. M. Saussure, by melting together, more or less thoroughly, certain quantities of horn-rock, marl, and schistus, has produced imitations of these lavas. (*Voyage dans les Alpes*, p. 127).

XXI. Siliceous earth, united with about a tenth part of magnesia, and a very small portion of calcareous earth; pumice-stone.

Species.

XXII. Siliceous earth, with less than its own weight of magnesia and iron; martial magnesian spar. Pisolite found at Sainte Marie, by M. Maret.

XXIII. Siliceous earth, with one-third its own weight of aerated calcareous earth; Turkey stone. Oil hardens it.

XXIV. Siliceous earth, mixed with a little iron and calcareous earth. Rag-stone.

XXV. Quartz consolidated with less than its own weight of calcareous earth or clay, and a little iron; grit reducible to sand by pounding. Var. I. Grit with a calcareous cement; of Fontainebleau: it effervesces with acids. II. With an argillaceous cement. This variety does not effervesce. It is used for building, for whet-stones, and for filtering water, &c.

XXVI. Siliceous earth consolidated with semi-phlogisticated calx of iron; brown or black scintillating stone, which becomes red and exfoliates in the air. Semi-phlogisticated iron agglutinates earths; but iron, when very much calcined, possesses not the same agglutinative power. This fact has been demonstrated by Messrs Edward King and Gadd.

To these twenty-six species of the siliceous genus, Mr Kirwan annexes six other species in which that earth predominates. The varieties which he includes under these species, are compounds frequently found

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in mountains of ancient formation. The English chemist draws this supplement to the filiceous genus from M. Sauffure's observations on the Alps. Among these varieties are, the several kinds of granite, pudding-stones, granitelloes, granitines, porphyry, gneis, vario-lite, &c.

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CHAP.

C H A P. IV.

Of the Chemical Analysis of Earths and Stones,

THOUGH, within these few years, the chemical analysis of earths and stones has been much more industriously prosecuted than at any former period, yet still it must be confessed, that our knowledge of their component principles is far from being sufficiently extensive or accurate, to be assumed as the foundation of a methodical arrangement of them. Hence the diversity of the chemical classifications of these substances which have been hitherto offered to the public; and for this reason have we been induced to give an account of the different methods successively proposed by three celebrated chemists in the course of a very short period of time.

The chief advantage which has been gained from the various researches of late made into the nature and component principles of earths and stones, is the discovery of proper means for distinguishing these. The method of analysing these substances is not a little complex; and I mean to give only a general account

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of it in this chapter. In fact, as the student of chemistry, who has read only the foregoing part of this work, though acquainted in some degree with the phænomena of fire, air, and water, must be entirely ignorant of the properties of saline bodies, which are so efficaciously employed in separating and examining the constituent principles of earths and stones; if we were here to speak of the use of solvents in analysing these matters, we should both deviate from that order and regularity which are so necessary in laying down the elements of physical science, and likewise run the risk of becoming unintelligible: I shall therefore reserve a minute and particular account of the chemical decomposition of earths and stones by acids and alkalis to a different part of the work*, explaining here nothing but its general principles.

When we wish to discover the chemical properties of a stone or an earth, we must begin with a careful examination of its physical properties, its form, hardness, gravity, colour, &c. The extraneous substances, of which there is always a greater or a less quantity mixed with such bodies, must next be separated from it, so as that it may be purified from all mixture, by picking, washing, &c. A stone should be reduced to powder, or, if the expression may be allowed, to the state of earth, before we attempt to examine its principles. The first trial that is made is generally with fire. A few ounces are exposed in a well-baked crucible of clay or porcelain, to the heat of a strong furnace, such as Macquer's; that of a potter's or a glass-maker's is still better for the purpose. It is to be observed of the crucibles used in this operation, that the
argillaceous

* See the treatise on the *Analysis of Waters*, at the end of this work.

argillaceous earth of which they are chiefly composed has often a considerable share in producing the alteration which the stony substance seems to suffer from heat: but we have no way of avoiding this inconvenience; and indeed it becomes of little consequence in a comparative analysis of a great number of stones. Of late years, the use of the blow-pipe for treating mineral matters with fire, has been introduced; and in the chemical examination of an earth or a stone, this instrument may be employed together with the above described means for decomposition. Those substances are exposed to the fire, either alone or several of them mixed together, or with a mixture of some saline matters to be afterwards described *. Lastly, they may be likewise treated with a machine for pouring vital air on coals, of which I have given a description in my *Memoires de Chimie*, and which produces a heat that for intensity may be compared to the focus of a glass lens, such as that of the academy. These operations produce either a fusion more or less perfect, or some change of colour, consistency, form, &c. which is to be carefully described. The process must be farther carried on, by putting the stony matter into an earthen retort, fitted up with a receiver and a pneumato-chemical apparatus †, in order to collect whatever water and aeriform fluids may be disengaged. Matters which afford these products are properly salino-earthly substances, though they be considered as stones

by

* See Bergman's paper on the blow-pipe, with Mongez's notes *Manuel de Mineralogiste*; or Cullen's English translation of Bergman.

† See a description of this apparatus under the article *Gaz* of the Chemical Dictionary, in M. Sigaud de la Fond's work on the different kinds of air. A.

by naturalists; yet, as they are often found mixed with genuine earths, it is therefore proper to mention here the general mode of examining them. The action of fire shows whether a stone be siliceous, aluminous, or mixed. But as most stones are of the latter kind, and many of them consist of several, some even of five or six, different substances united in various proportions, other processes are likewise to be employed for determining the principles of their composition. These consist in treating them with several acid and alkaline solvents, the successive application of which separates all the principles of which they consist.

The action of air, and of water in vapour, may likewise contribute to make us understand the nature and constituent parts of earthy and stony matters. Some of them suffer no alteration from these agents; others are divided, and gradually assume a new form, colour, and consistency. These phænomena belong chiefly to stones of a very compound nature, and containing much iron. Lastly, lixiviation with cold and warm water, shows whether they contain saline matters, however difficult it may be found to bring these to solution.

Such are the means by the use of which modern chemists have been able to determine the nature and the component principles of so great a number of earths and stones. I have here given but a very short and general account of them. In the history of saline matters, we shall give all those particulars concerning them which cannot be conveniently or advantageously introduced here.

SECTION

SECTION II.

CHAP. I.

Of Saline Substances in general; their Characteristics, Nature, and the Method of arranging them.

SALINE substances, of which there are a very considerable number, possess peculiar properties by which they are distinguished from those which we have hitherto been examining. The properties which have been employed by chemists as characteristics of saline matters, are such as leave their real nature somewhat uncertain: being common to many other bodies besides salts, they extend this class of substances far beyond its just limits. Taste and solubility in water, which have been always given as characteristics of saline substances, belong to many bodies which are not saline; as for instance, to all mucilages and animal matters. These two properties again exist in a very low and imperfect degree in several saline substances. Naturalists have not been more accurate in their definitions of salts: the transparency and crystalline form which many naturalists have considered as peculiar to

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them, belong equally to many other matters, especially earths, while some salts are quite destitute of them. Macquer has, therefore, asserted, with great truth, that the true limits which divide saline matters from other classes of substances are not well known.

Yet as we *must* take *some* side, and form some determinate notions concerning the properties of these matters, we shall take a general view of them, before proceeding to the history of each particular salt.

We acknowledge as saline substances, all such as possess the greater part of the four following properties: 1. A strong tendency to combination, or affinity of composition: 2. A stronger or fainter taste: 3. A greater or a less tendency to solution: 4. Absolute incombuftibility. Before proceeding to consider each of these properties by itself, we must observe, that in proportion as a body contains more or fewer of them, and those in a greater or less degree, it is more or less of a saline nature. From this, however, we must not conclude, that matters possessing these properties but in a very faint degree are not saline. Were we to admit such a principle, we should expose ourselves to frequent errors; as it sometimes happens that two salts, which in a solitary state possessed these properties in a very low degree, afford still fainter indications of them after being combined. In such cases recourse must be had to chemical analysis, which, by separating the substances, will render their chemical properties more observable.

§ I. *Tendency to Combination considered as a Characteristic property of Salts.*

MOST salts have a tendency to combine with many different substances. Among salts we find the most active bodies in nature, capable of forming an infinite number of combinations, by entering into union with others. Chemists have, therefore, always made most use of saline matters; some of which they have honoured with the names of *solvents* and *menstrua*. Yet this tendency to combination is far from being the same in all salts. Some of them possess it in so strong a degree, that they corrode and destroy, or dissolve whatever touches them, even vitrifiable and quartzose stones not resisting their attacks; such is the power of many of those pure salts that are known by the names of *acids* and *alkalis*. Others, though not possessed of such a force of combination, unite readily with many bodies. Lastly, there are some among them, whose tendency to combination is but very trifling, and scarce superior to that of earthy matters. But the cause why, in these latter, the tendency to combination is so small is, their being in a great measure saturated, as is observable of most neutral salts. After this, we cannot well be surprised that salts are scarce ever found in a pure or solitary state in the bowels of the earth.

§ II. *Taste considered as a Characteristic of Salts.*

TASTE has been always considered as so essential a property of saline substances, that several philosophers have considered them as the only bodies in nature possessed of this property, and the principle of all taste. Though this opinion be not demonstratively certain, as there are many bodies, such as metals, which have a discernible taste, though not saline, while, again, several saline substances have scarce any taste; yet it must be acknowledged, that most salts possess the property of taste; and this property is therefore to be considered as one of their leading characteristics. The taste of salts, like their other properties, is different in different species. In order to understand aright on what circumstances it depends, and whence the causes of its varieties, we must first endeavour to distinguish what constitutes the peculiar nature of this property. By taste, we usually understand an impression made on a certain organ which nature has given us for the purpose of distinguishing by it some material body, and from which we judge of that body as useful or noxious, and determine either to make use of it or reject it. It is therefore the action of the sapid body on the nerves of the tongue and palate of animals, which informs them that one substance may be of use, or another hurtful to them. But can this property of bodies affect only the nerves of the tongue? will it not act with equal force on the whole nervous system? Those who are acquainted with the phenomena of the animal œconomy, that the action which constitutes taste or sapidity,

dity, must affect all the other nerves, and must always be proportioned to the sensibility of the subjects and the organs on which it operates. This idea of taste naturally leads us to think, 1. That this quality of bodies will make almost no impression on such parts of the body as have but few nerves, or of which the nerves have but little sensibility, on account of their being covered; as on the skin where they are defended by the reticular membrane and the epidermis. 2. That this quality of bodies will act with the most energy on those organs in which the nerves are largest, most numerous, and of a form the most proper for receiving an extensive contact, and a violent emotion from salts; the epidermis being so thin as to leave the nerves almost naked. The superior surface of the tongue, the roof of the mouth, and all the innert part of the mouth in general, are susceptible of the sensation of taste, from a vast number of bodies which make no such impression on the less delicate sensibility of the other parts of the skin. 3. That bodies which have no taste and no power of affecting the skin, may notwithstanding this act upon organs which are more delicate, and have nerves of greater sensibility, such as the stomach and the intestines.

Admitting these facts, we may distinguish tastes and sapid bodies into three classes, under which all the saline substances that we are to examine may be arranged. The first class comprehends such salts as have the strongest taste, and affect the skin in the most sensible manner. The impression of these salts is so powerful, that it occasions a very lively sensation of pain; and where its action is continued for some time, it entirely destroys the organization and texture of the skin. This property is called *causticity*, and the salts

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which possess it are named *caustics*. The second class consists of salts which have a milder taste, and affect only the nerves of the organs through which we receive that sensation: these are distinguished from one another by names expressing the several impressions which they make on those organs; such as bitterness, astringency, acidity, acridity, urinous taste, &c. To the third class we shall refer saline substances, the taste of which is sensible only to the stomach and the intestines; but the number of these salts is very scanty.

Some observations are necessary on the mutual relations of these several classes of salts. It is first to be observed, that between those which possess the peculiar properties of any of the three classes in the weakest, and those which possess the same properties in the strongest degree, there are many varieties; there are stronger and weaker caustics; some instantly destroy the texture of organized substances, others require a considerable time to produce that effect. The same fact may be observed of bitter, astringent, or urinous salts, as well as of those which act only on the nerves of the stomach. Secondly, When we consider these varieties of the several classes, we are naturally led to think, that all tastes are but different degrees of the same property, from that of the strongest caustic salt to that of the saline substance, whose action is scarce sensible to the nerves of the stomach. This observation implies, that all tastes actually depend on the same cause, and participate of the same principle.

We cannot adopt an happier method for distinguishing the cause of taste, than to consider that taste which is the strongest of all, observe its phenomena, and attend to its action. Causticity must therefore be the subject of our consideration: a property which has always attracted the curiosity of chemists. Lemery, ob-

serving that very hot bodies were usually very caustic, and that all salts possessing the property of causticity have been strongly heated before acquiring it, ascribed this property to the particles of fire lodged in caustic bodies. M. Baumé has implicitly adopted Lemery's opinion. Meyer, an apothecary of Osnaburgh, made a series of researches into the nature of caustic salts, and formed a very plausible theory, which was at first warmly embraced by a number of chemists, but is no longer mentioned with the respect which it once obtained. He attributed causticity to a principle which he considered as a compound of fire and a peculiar acid: this, in imitation of the ancient chemists, he named *causticum*, or *acidum pingue*. He traced it thro' its various combinations, as Stahl had done with phlogiston. But his system has the same defect with Stahl's; the existence of his *causticum* has not been demonstrated. Dr Black, by a series of experiments on the same matters which Meyer examined, has levelled the severest blow against his theory; proving, by rigid demonstration, that lime and alkalis, instead of deriving their causticity from a *fat acid* principle, become acid in consequence of losing a salt, to be afterwards mentioned under the name of the *Carbonic Acid*.

Macquer has undeniably been the most successful inquirer into the cause of causticity. The doctrine which he lays down on that article in his Chemical Dictionary is so plain, and supported by such conclusive facts, that we cannot refuse assenting to his opinion. After observing that caustic bodies destroy and corrode our organs, by entering into combination with the principles of which they are composed, he remarks,
that

that in proportion as this combination takes place, the caustic gradually loses its strength, and becomes absolutely destitute of causticity, when it has dissolved as much of the animal matter as its force and quantity are equal to. Thus the *lapis causticus*, or pure fixed alkali, gnaws and corrodes the skin when applied to it; but loses its corrosive and solvent power when it ceases to act on that organ. This salt really acts by a chemical power, for it exerts its force even on the insensible skin of a carcase; as M. Poulletier has shown by accurate experiments, and on all animal substances in general. Causticity therefore depends on tendency to combination; and the sensations with which it affects our organs are occasioned by the combination of the caustic with the matter of which the organs are composed. In the same manner a caustic loses its virtue in the laboratory, by combining with any substance with which it has a strong affinity; and in a word, the causticity of a body is always in the proportion of its tendency to combination. That salt which has the faintest taste is already saturated with some substance; and by separating it from that substance, we cause it to regain a taste, stronger or weaker, according as the separation is more or less complete. The whole history of saline matters concurs to support this opinion, as will appear in what follows.

§ III. *Solubility considered as a Characteristic of Salts.*

SOLUBILITY in water has been given by all chemists as one of the most eminent characteristics of salts; yet this property, like taste and tendency to combination, is subject to varieties. Some salts possess it in such a degree, that without very long and refined processes, it is impossible to separate them entirely from water. Others are not so extremely soluble, and the degrees of their solubility may be precisely ascertained; as, for instance, most neutral salts. Lastly, There are some saline substances, whose tendency to solution is so faint and indistinct, that they seem to differ more in nature from the other classes of salts than from earths and stones; and all salts of this character have been by most naturalists considered as earths and stones. It is indeed extremely difficult to fix the precise limits between these two classes of mineral bodies; and chemists have not as yet agreed in determining them. Mr Kirwan, in his mineralogy, seems to have adopted Bergman's opinion; who thinks that all substances are to be considered as earths, which require more than a thousand times their own quantity of water to maintain them in a state of solution, while all such as are soluble in a smaller proportion of water, should be distinguished as salts. Were this proposition generally received among chemists, as I think it well deserves to be, that diversity of opinions and terms which has hitherto prevailed on this point might be avoided; and they have a direct tendency to render the

the sciences.

The resulting bodies are precisely and tend to relations of solution with a laws with the more readily and variably depends

§ IV.

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the science more obscure and perplexing to beginners.

The relation which I have taken notice of, as subsisting between the taste and the solubility of salts, is precisely the same with that which subsists between taste and tendency to combination. The cause of these relations may be easily understood by observing, that solution in water is a real chemical union of a salt with a fluid, and must therefore depend on the same laws with taste and tendency to combination. In fact, the more taste and solvent force a salt has, the more readily does it dissolve in water. This law holds invariably with regard to all saline matters, and even depends on their nature and essential properties.

§ IV. *Incombustibility considered as a Characteristic of Salts.*

IT is more difficult to form a determinate idea of this fourth than of the three preceding characteristics of saline matters. No chemist has as yet considered these substances under this point of view. A number have even thought, that some salts, and among others nitre, are actually combustible.

In order to see clearly that this is a mistake, and that all mineral saline substances are absolutely incombustible, the student of chemistry must have a much fuller knowledge of the properties of those substances, than he can have acquired from perusing the foregoing part of this work. However, as we think this one of the most essential and important characteristics of salts,

we shall here give a short view of the doctrine which we are induced to advance on this head, and which will be fully illustrated and incontrovertibly established, in our particular examinations of saline substances.

It appears from M. Lavoisier's fine experiments, that many combustible matters form by their combustion peculiar acids. Combustion, as above explained, is nothing but the combination of the base of vital air, or the oxygenous principle with combustible bodies. Every body which has been completely burnt, that is, which has been saturated with the oxygenous principle, returns into the class of incombustibles; or what is just the same, its tendency to combine with the oxygenous principle is satisfied, and it cannot unite with a new quantity of oxygen, or absorb any more of it. This being admitted, it plainly follows, that, as a number of salts are residues of various combustible bodies, and even an entire class of saline substances are found to have oxygen for one of their principles, and exhibit the characteristics of substances which have been exposed to combustion, these cannot be any longer susceptible of combustion. A numerous train of facts, which shall be hereafter related, concur to justify these assertions: they prove salts to be compound bodies, most of them formed by the union of certain combustible bodies with the oxygenous principle. From this it is easy to understand that incombustibility deserves to be regarded as one of the most certain and invariable characteristics of saline matters. We hope that this will be completely demonstrated of the class of acid salts, when we come to enter particularly into the history of those substances.

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Yet there is one class of salts which, though evidently compound bodies, are not known to contain any portion of the oxygenous principle: all the alkalis are of this class. But these are either compounds of incombustible bodies, or if some combustible matter enters into their composition, as we shall have occasion to observe of ammoniac or volatile alkali, it is united with some substance evidently incombustible, which hinders the combustibility of the other matter from being observed.

§ V. *Of the general Nature and Composition of Saline Matters.*

STAHL, after studying the nature of salts with much attention, was persuaded that they were generally formed of earth and water. He collected all that chemical researches could supply to support and illustrate his theory. But since that illustrious æra of chemical science has been succeeded by one still more illustrious, for both the multiplicity of the researches prosecuted, and the importance of the discoveries which these have produced; Stahl's theory, which is very perspicuously explained in the works of Macquer, is no longer sufficient to explain the nature and composition of salts. We are no longer content with those remote analogies which forced the most discordant facts into an unnatural union, and bewildered the understanding by exhibiting to it illusive lights. Philosophers now choose rather to confess their ignorance, than to advance ill-founded theories, which may sooner or later be refuted by experiment.

Although the chemical nature of salts be not yet entirely known, and facts allow us not to agree with some of the most eminent philosophers, in acknowledging one saline principle as the base and element of all salts; yet the component principles of this singular and numerous class of substances are somewhat better known now than formerly. We know that most of them contain a very considerable quantity of the oxygenous principle; which principle is fixed in some combustible matter. This has been fully shown to be the composition of a number of acids; and we have the strongest reason from analogy to conclude, that most other salts of that class have the same character. Water, though not one of the immediate principles of salts, is often found united to them, and has a strong affinity with them. As to the matter of fire considered as phlogiston, which some of the most eminent chemists have admitted as a component principle in salts, the nature and existence of that matter are too uncertain to admit of our adopting any determinate opinion in respect to it. The case is not the same with the caloric principle; it seems evidently to constitute one of their component principles; in some, however, it exists in a much smaller proportion than in the rest, which appear in general to owe to it their fluidity, fusibility, and volatility. The existence of earth in any considerable number of salts has never been experimentally demonstrated. We know only that all the saline bodies which nature exhibits, are mixed with a larger or a smaller quantity of various earthy substances. But these, properly speaking, do not belong to them; they form no part of their composition, and may be said to be only accessories. The only substances at present acknowledged as general principles of saline matters, are

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several combustible bodies, the oxygenous principle, a few incombustible matters, and the caloric principle. It is well known that most acids are residues of burnt bodies, and contain oxigene and combustible matter combined together in various proportions. Whatever more has been advanced in treatises on chemistry concerning the nature of salts, is nothing but ingenious or ridiculous hypothesis, unsupported by any solid basis of facts.

§ VI. *Of the Division and Arrangement of Mineral Saline Matters.*

THE salts belonging to the mineral kingdom are very numerous. A number of them are products of nature, formed by the action of fire, water, and air, and by the dissolution of organic matters. But most of those which are employed in chemistry owe their formation to art, or at least have not hitherto been found among the products of nature. In order to give a methodical view of the history of these substances, we shall divide them in the same manner as stones, into orders, genera, and species. All saline matters may be arranged under two orders.

The first contains those saline substances which have been named *simple*, and which we shall distinguish by the name of *primary salts*, because they serve as principles to those of the second order.

The second consists of the secondary, compound, or neutral salts. These are formed by the combination of
two

two or more of the former order, and are of consequence much less simple than they.

Each of these orders shall be divided into several genera, and these again into species.

Nine genera, and eighty-six species of simple and compound salts together, are at present known to exist in the mineral kingdom; and these we shall successively examine *.

* There are three salino-terreous substances, three acids, and ten mineral acids. These last, united with aluminous earth, with the three salino-terreous bases, and with the three alkalis, compose 70 compound or neutral salts. A.

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CHAP. II.

*Of the three Salino-Terreous Substances *.*

ORDER I. SIMPLE or PRIMARY SALTS.

WE give the name of *simple* or *primary salts* to those matters which were formerly known by the name of *simple salts*, and are still so called by some chemists. As it has been shown by fair experiments that most of them are really compounds, therefore the title of *simple salts* cannot with any propriety be applied to them, except when they are compared with the salts of the second order. The name of *primary salts* seems the most suitable for distinguishing them, because they form by combination those neutral or compound salts which we call *secondary*. We shall divide this order into three genera, *salino-terreous substances*, *alkalis*, and *acids*. The examination of the first will occupy this chapter; in the two following we shall give the history of *alkalis* and *acids*.

Genus

* The title of this chapter is the general denomination of the first genus of the first order of *simple* or *primary saline matters*. A.

Genus I. *Salino-terreous Substance.*

By this name we denote three substances which have been hitherto regarded as earthy matters, but whose properties plainly show them to be more properly saline*. As these substances possess the distinguishing properties of salts, in conjunction with the characteristics of earthy matters, yet, displaying the latter in a less eminent degree; we therefore rank them before the salts, using them as a link of connection between salts and earths: They differ also from earths as having a stronger tendency than these to combination, as will appear from an examination of their properties.

It is proper to observe, that in our examination of these salino-terreous matters, as well as in our account of the primary salts, we suppose them pure and solitary, though they be never found so in nature; and we avoid mentioning the methods by which they are obtained, from a desire not to break through that elementary order which we have determined to follow through the course of the work. When we come, in the history of neutral salts, to give an account of their decomposition, we will then have occasion to describe the methods by which chemistry separates those substances, as well as the simple or primary salts, so as to afford them pure.

This first genus contains three species of salino-terreous bodies.

Species

* We have already given some account of them in lithology; but then only as making a part of natural history. A.

Species I. *Barytes*.

THE first name of this substance was *ponderous earth*, given it by the Swedish chemists Gahn and Scheele, who discovered it in ponderous spar: Bergman and Mr Kirwan have already given it the Latin name *barytes*. Its specific gravity, according to Mr Kirwan, is something more than 4000. Nature no where affords this earth in a pure but always in a combined state. It was first discovered and distinguished as a peculiar earth by the chemists above-mentioned. Messrs Margraf and Monnet had observed it, but confounded it with absorbent or calcareous earth. Yet the last of these chemists had observed it to possess some peculiar properties, and suspected it to be an earth of a different nature from lime. Its properties, in a pure solitary state, have not as yet been very accurately examined: its combinations have been more studied; and what most eminently distinguishes it from other analogous substances, is its very singular affinities, and the salts which it forms by combination with acids.

Pure barytes, obtained by means which shall be afterwards described, appears under a pulverulent form, very fine and white. I have never found it to affect the tongue with any discernible taste.

It is not yet known whether this substance be liable to alteration from light.

The ordinary fire of our furnaces does not reduce it to fusion: But if heated in a clay crucible, it communicates a blue or greenish colour to the crucible, and assumes itself a slight tinge of the same. This phænomenon seems to arise from its power of re-action on clay.

M.

M. d'Arcet says, that it melts when exposed to a very violent heat in a clay or iron crucible.

When exposed to the air, it acquires an accession of weight, and combines, though very slowly, with the carbonic acid contained in the atmosphere: the effects of vital air upon it are unknown. We are equally ignorant of the manner in which the oxygenous and the azotic principle act upon this saline earth. The azotic is perhaps one of its constituent principles.

It dissolves in water, but not without difficulty; for 900 parts of that fluid are requisite to dissolve one of barytes. Water thus saturated gives a pale green colour to the tincture of violets *, and still more readily to that of mallows or radishes. This solution, when exposed to the air, is covered with a thin pellicle; and if stripped of it, a new one is produced. This phenomenon is owing to the carbonic acid in the atmosphere: the same thing happens to lime-water, though in a less eminent degree. The solution, when evaporated in close vessels, leaves a residue of barytes; and the weight of the residue affords a proof of the solubility of that substance. It is almost unnecessary to observe, that in this, as in all other processes of the same nature, distilled water is to be used.

Barytes acts but very feebly, either by the humid or the dry way, on siliceous and aluminous earth †.

Yet

* By tincture of violets, we mean a solution of the colouring part of violet flowers in water. This tincture when newly made is preferable to the syrup of violets, as being much easier affected. But the syrup may be employed in all instances in which the saline matters under examination act with a determinate energy; and we shall therefore often mention it instead of the tincture. A.

† We must here observe, that in order to give a regular account of the

Yet it facilitates the fusion of those earths, and assumes a blue or greenish colour when heated with the latter of them. Barytes is less copious in nature than either of the other two salino-terreous substances; but it is probably more copious than it is thought to be. Formerly, it was not known to exist in any body but barytic sulfate or ponderous spar; it was some time since found in England, combined with the carbonic acid, and crystallized like a transparent spar. That salt will be afterwards described. Some modern chemists think it to be a metallic calx or oxide. Its weight, that of the compounds into which it enters, and the precipitate which it affords, when a solution of it with an acid is mixed with an alkaline prussiates, made Bergman long suspect it to be of that nature. We are told, that M. Gahn, a scholar of that celebrated chemist, has actually obtained the barytes under a metallic form; but this fact needs confirmation. Its nature therefore is still unknown; because we have never yet been able to separate its principles, or imitate its composition. I suspect, as I have already hinted, that the azotic principle, or the base of mephitic air, is one of its component parts.

Pure

the reciprocal action of bodies on each other, no combination of any two bodies is mentioned till after those two have been described. Thus in the history of barytes, I have mentioned only the manner in which it is affected by light, by the caloric, the oxigenous, and the azotic principles, by water, and by siliceous and aluminous earth, because none but these have as yet been described. As we advance in the history of natural substances, we shall learn all the combinations of which it is susceptible. Thus we shall both preserve our order inviolate, and communicate all the necessary information concerning the matters of which we treat. A.

Pure barytes is not applied to any use; solutions of it in water in acids are used as re-agents, as we shall elsewhere have occasion to observe.

Species II. *Magnesia*.

THAT magnesia which is obtained from Epsom salt, or sulfate of magnesia, and which is likewise found in mother water of nitre, and in a great many stones, &c. is no where in nature to be met with in a state of purity, but always combined with acids. Dr Black is the first chemist who has accurately determined the distinction between it and lime.

This substance, which is obtained by methods to be afterwards described, appears under the form of a very fine white powder, resembling meal both in appearance and to the touch. Its gravity, according to Kirwan, is about 2.33. It has no taste sensible to the tongue; but it affects the stomach as a gentle purgative. It communicates a pale green to the tincture of violets and mallows, and causes turnsol to assume a blue colour. The manner in which light affects magnesia is not well known: it cannot be very powerfully.

According to the experiments of M, d'Arcet, this substance does not melt when exposed to a strong heat. Macquer too observed, that it remained unaltered in the focus of the burning lens of the garden *De l'Infante*. M. Morveau heated magnesia for two hours in the strongest fire that can be produced in Macquer's furnace, with the same effect. M. Butini, a citizen of Geneva, who has published some valuable experiments on magnesia, has observed, that violent ignition contracts and condenses magnesia in such a manner as

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to render it capable of attacking and corroding an iron surface. We are informed that a small cube formed of a paste of magnesia and water, and exposed to the focus of Parker's lens, was suddenly contracted in all its dimensions. This property seems to indicate a relation between magnesia and aluminous earth; which two substances are often found combined together in nature, as was observed in the history of steatites, asbestos, and serpentines, &c.

Magnesia, though heated in a retort, loses not the portion of water which it contains: but when subjected to this process, it acquires a very discernible phosphoric quality, as has been observed by M. Tingry, apothecary at Geneva. It suffers no alteration from air till after being long exposed to it. M. Butini kept ten grains of calcined magnesia in a porcelain saucer covered with paper, in a dry room, for near two years; the only change which it suffered was by gaining one-eighth of a grain of additional weight. It appears that this substance combines slowly with the carbonic acid diffused through the atmosphere.

It dissolves in water but imperfectly and with great difficulty. Four ounces and two drams of pure water, after standing three months in a bottle, with a dram of calcined magnesia, and being boiled together with that substance, afforded M. Butini, by evaporation, a residue which he estimated at one-fourth of a grain.

Mr Kirwan says, that 7692 times its own weight of water is necessary to dissolve it in the ordinary temperature of the atmosphere; that is to say, at about 60° of Fahrenheit's thermometer. Notwithstanding this aversion to solution, magnesia forms a kind of paste with water: that paste, indeed, is not ductile, but brittle; and the water is readily separated from it by

the action of fire, or even of the dry atmosphere. A solution of magnesia has no sensible taste; and it produces but a very trifling alteration on the colour of syrup of violets.

We are not yet well acquainted with the manner in which magnesia acts on pure earths. We know, however, that it does not vitrify with either siliceous or aluminous earth separately; but when heated with both together, it is susceptible of fusion.

Its action on barytes has not yet been examined.

The intimate nature of magnesia is not better known than that of barytes. It has never been shown by experiment to be a modification of some other saline substance, as some chemists have imagined it to be; for magnesia has not yet been either separated into principles by analysis, or imitated by a synthetic process. In the present state of chemistry, therefore, it is to be considered as a simple substance.

Pure magnesia, which Dr Black calls *caustic*, is used in medicine as an absorbent and purgative. For heartburnings and other complaints occasioned by acidity, it is preferable to common magnesia: because the carbonic acid which this last contains is disengaged in the primary passages by the acids, and produces flatulencies, with all that train of complaints which accompany them: it preserves flesh for a long time, and even restores putrefied bile. Bergman ascribes to it likewise the property of rendering camphor, opium, resins, and gum-resins, soluble in water, and of forming some valuable dyes; though caustic magnesia be scarce soluble in water. These preparations are unknown in France.

Species

Species III. *Lime.*

QUICKLIME is a white substance, of more consistency than the two preceding matters: it appears in the form of a grey white stone. Its taste is hot, acrid, and urinous; it possesses this property in so considerable a degree as to inflame the skin when applied to it. Its specific gravity is about 2.3; its form pulverulent and friable; it is found in places adjacent to volcanoes; as M. Monnet has observed on the hills of Auvergne.

Lime turns syrup of violets green, giving it a much more intense colour than it acquires from either barytes or magnesia: indeed, it almost destroys the original colour, and in a short time produces in its stead a dirty yellow.

Lime, when exposed to a strong fire, such as that of a glass-house, remains unaltered; and, in a solitary state, it is not susceptible of fusion. Parker's burning-glass appears to have brought it to the beginning of fusion; but the lime was placed on a support of charcoal. When heated in a clay crucible, its edges sometimes appear to melt; but this phenomenon is occasioned by its acting on the earth of the crucible.

When exposed to the action of the air, lime swells, breaks, and falls into powder; it then increases greatly in bulk, and is called *lime slaked in the air*. These phenomena are more remarkable, and take place more rapidly when the air is in a humid state. This dry slaking produces heat; and the dilatation is so considerable as to burst casks, or other wooden vessels in which lime may be contained. After being slaked with air, this substance appears under the form of a very fine

white dust; it has acquired a very considerable increase of weight, and its taste is become much fainter. These phenomena are occasioned chiefly by the water contained in the atmosphere, and the force with which the lime tends to unite with it. And by heating lime which has been flaked with air in a retort, till it becomes red-hot, water is obtained, and the lime returns to its original state.

Water acts very powerfully on quicklime. Pour a small quantity of that fluid on a quantity of lime, the water is instantly absorbed; and the mass of lime appears as dry as before; but it soon bursts and breaks into pieces. The heat excited in it by this operation is so strong, as to produce a remarkable hissing noise: the water is reduced to vapour of a peculiar smell, which communicates a green colour to paper tinged with mallows. The lime soon falls down to a powder; and the heat, motion, and smoke, gradually disappear. If the process is performed at night, in a place perfectly dark, a great many luminous points are observable all over the surface of the lime. All these phenomena depend on the activity with which this salino-terreous substance unites with water. But, in order to produce them, we must employ but a very small portion of the fluid; only so much as the lime can absorb without appearing wet. It appears that the heat disengaged from these two bodies, when they combine with such rapidity, changes their state; and that the lime, when flaked, and reduced to a state of pulverization, contains water in a dry and solid form. This dry state of water which takes place in many of the combinations in which heat performs a part, and produces solid compounds, whose specific heat is less than that of the bodies of which they are formed, has not yet sufficiently

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engaged the attention of chemists; indeed it has been but lately observed. When lime has absorbed as much water as it can contain, without becoming wet, it is then called *dry flaked lime*; water no longer excites any heat in it, and only dissolves it without producing any very discernible motion. By mixing lime with a proper quantity of water, we obtain milk of lime; and by adding so much water as may be necessary to effect a complete solution of this salino-terreous matter, we produce a liquor perfectly transparent. Mr Kirwan says, that about 680 times its weight of water is necessary to maintain it in solution at the temperature of 60°.

This solution, which is known by the name of *lime water*, is clear and limpid. It is but very little heavier than common water, has an acrid urinous taste, communicates a deep green to syrup of violets, and even produces upon it an entire alteration of colour. Lime-water, when evaporated in close vessels, affords very pure water, leaving a residue of quick-lime at the bottom of the vessels: But this residue needs to be very strongly heated, in order to separate entirely the water which still adheres to it: After which that fluid excites heat in it in the same manner as before its solution.

Lime-water, when exposed to the air, is covered with a dry pellicle, which becomes gradually thicker and more solid. If the first pellicle be taken off, a second is formed, and this process may be repeated till all the water be evaporated. These pellicles have been improperly termed *cream of lime*. This was formerly thought to be a peculiar salt, formed by the union of the finest calcareous earth with water; and much has been written concerning this pretended salt of lime. But it is now well known from the experiments of the celebrated Black, that the cream of lime possesses sa-

lime properties less active than those of lime, and that it is a peculiar neutral salt formed by the combination of lime, with a certain acid contained in the atmosphere; and the cream is never formed on lime-water, except when it is exposed to the air. We will elsewhere examine this salt under the name of *carbonate of lime* or *chalk*. The manner in which the oxygenous and the azotic principle affect lime is not yet known; it is probable that this base absorbs and fixes some part of azotic gas, and at least contains the base of that gas.

Lime combines with siliceous earth in both the humid and the dry way. If sand be mixed with lime newly slaked, or with quick-lime sprinkled with a small quantity of water at the time of mixing, the two bodies become consistent, and form what is called *mortar*. This mixture is liable to many varieties; from the state and quantity of the quick-lime, the quantity of water with which it has been slaked, the circumstance of the sand being mixed with it at the instant of its slaking, or not till some time afterwards; and from the size, the roundness, the inequality, the moisture, or dryness of the sand*. Mortar is also composed of clay baked into bricks, and of puzzolana, which is nothing but clay baked by volcanic fire, and altered by the contact of the air.

Though lime, as well as siliceous earth, be absolutely infusible by itself; yet if these two substances be heated together, the former in a greater proportion than the latter, they are susceptible of fusion, as has been observed by Messrs d'Arcet and Gerhard. Lime likewise melts with a quantity of aluminous earth equal to one-third of its own weight; and Mr Kirwan shows, that

* See Recherches par M. de la Faye, sur la preparation que les romains donnoient à la chaux, Paris 1777-8, premiere et seconde partie. A.

that it has a greater affinity with this than with siliceous earth. A mixture of all the three substances melts easier and more completely than a mixture of lime with any one of the other two. Thus one part of lime and one of aluminous earth will occasion the fusion of two parts, or even of two and an half of siliceous earth. From this fact we understand why so many stones, apparently hard, scintillating, and quartzose, melt notwithstanding, when exposed to a strong fire. The combination, or even the mixture of calcareous earth and clay, with siliceous earth, occasions this phenomenon.

It is not yet known in what manner lime acts on barytes.

One part of calcareous earth produces the fusion of one-half part of magnesia. The glass formed by this mixture, in fire completely dissolves and reduces to fusion a quantity of siliceous earth equal to the quantity of the lime. Accordingly, equal parts of magnesia, lime, and siliceous earth, when exposed to fire together, afford a perfect glass.

The intimate nature of lime is unknown. The first chemists who attempted to explain by physical reasonings the phenomena which lime displays in its combinations, and especially when flaked, ascribed them to the fixation of particles of fire in the calcareous stone during its calcination. Such was Lemery's theory. Meyer was of opinion that pure fire was not susceptible of such a combination, and that there was a peculiar acid which combined with it in the lime. This subtle kind of sulphur was the *acidum pinque*, or *causticum* of that chemist. But this doctrine, which has since been repeatedly offered to the world under different names, is overthrown by a series of experiments clearly demon-

monstrating its falsity. Many modern chemists think, that the matter of heat is combined in lime; and that by its disengagement during the slaking of this substance, the light observed by Meyer and M. Pelletier, the ebullition and the evaporation of the water, as well as the peculiar fetid odour exhaled, on the occasion, are produced. It appears, however, from what has been said, that the principles and composition of lime are still unknown. Some very distinguished naturalists have thought it to be in all probability a certain preparation of siliceous or aluminous earth effected by the organs of animals; but that is by no means certain. It is surely, however, formed by marine animals; its constituent parts are certainly united and combined under water during the life of those organic beings; and the azotic principle is certainly *one* of its constituent parts: Yet all this is insufficient to determine the opinion of modern naturalists, who require accurate and repeated experiments.

Lime is made use of in many of the arts; more especially in building. In medicine, lime-water is successfully prescribed in ulcerous cases, &c. It has been thought a powerful lithontriptic. But long experience has shown, that it does not always operate the cures expected from it; and that where the use of it is too long continued, it produces on the animal fluids an alteration approaching to scurvy or septicity.

C H A P. III.

Genus II. *Alkali Salts.*

ALKALIS come to be treated of before acids, because they appear to be more simple and less decomposable, and because they resemble in some properties the salino-terreous substances. They have an urinous burning caustic taste: they turn syrup of violets green, excite heat in uniting with water, absorb both the moisture and the carbonic acid of the atmosphere, and dissolve earths by the strength of their tendency to combination. Three species of alkalis are known; potash, or vegetable fixed alkali; soda, or mineral fixed alkali; and ammoniac, or volatile alkali.

Species I. *Potash.*

THIS species, which we denominate *potash*, has been called *vegetable, fixed alkali*; because, though often met with in minerals, it is found in greatest abundance in vegetables. It has likewise been named *alkali of tartar*, because a considerable quantity of it may be obtained

tained from that saline substance; which will afterwards come under our examination. Dr Black was the first who discovered potash in a state of purity. Formerly this salt was called *caustic fixed alkali*, to distinguish it from common fixed alkali.

This salt, in a state of considerable purity, is white and of a dry solid form; its sapidity is so strong, that it dissolves the texture of the skin. It communicates instantaneously to the syrup of violets a deep green colour, much more observable than that which lime causes it to assume. It alters, and almost entirely destroys this colour, changing it to a brown yellow.

We know not in what manner light affects this salt.

Potash, when exposed to the action of fire in close vessels, is instantly softened, and by the time when it begins to appear red, becomes entirely liquid. If it be then poured on a smooth hard surface, it cools into a white, opaque, brittle mass. It is not decomposable by heat. A most intense heat, such as that of the furnace of a glass-house, is requisite to volatilize it. In all of these operations it dissolves part of the clay vessels in which it is contained.

When exposed to the open atmosphere, it attracts moisture strongly, dissolves into a liquid, and gradually passes into the state of a neutral salt, by absorbing the acid diffused through the atmosphere. For this reason, it acquired on such occasions an increase of weight, and becomes capable of effervescing with acids; which never takes place when it is in that state of purity in which we have supposed it. To preserve it pure, therefore, it must be kept in close vessels entirely full of it.

Potash dissolves very readily in water; it then ex-

cites

gives a considerable degree of heat, and exhales a fetid lixivious odour. The solution of it is colourless; and when very pure it affords no precipitate. To separate it from the solvent the solution must be evaporated to dryness in close vessels. If this operation be performed in open vessels, the acid of the atmosphere is attracted, and renders the pot-ash effervescent. And this absorption takes place so readily; that if a solution of this salt be exposed to the open air for ever so short a space of time, it suffers an alteration, and is in fact neutralized. In a flask which it does not entirely fill, and which is frequently opened, it is liable to the same alteration. The action of the oxygenous and the azotic principles on this alkali is not known.

Potash combines with siliceous earth in the dry way, and causes it to melt together with itself: the two compose a transparent body, known by the name of *glass*. This body is liable to varieties from the various proportions in which the siliceous sand and the fixed alkali are united in it. Two parts of the salt with one of earth afford a soft brittle glass, which attracts moisture, and becomes at length opaque and fluid. This glass is soluble in water, on account of its containing so much more than an equal proportion of alkali. The solution is called *liquor of flints*. It at length deposits part of the earth which it contains in white semi-transparent flakes, apparently mucilaginous, and so light that they subside but very slowly. Acids seize the alkali, and precipitate the earth, which is called *earth of flints*. But to make this process succeed, care must be taken that the liquor of flints be not too much diluted by the water. In that case, the particles of the earth being too much divided, remain suspended in the liquor, and evaporation is requisite to produce the precipi-

precipitate. Several chemists are of opinion, that earth of flints is not the same with siliceous earth; on which they think the alkali has produced an entire alteration. They think it to be more like aluminous earth, and believe that by combination with acids, it affords the same salts which are obtained by combining acids with aluminous earth. Such was the opinion of Pott and M. Baumé. But Scheele has shown, that that portion of the earth precipitated from liquor of flints, which is soluble in acids, is part of the aluminous earth of the vessel in which the operation is performed, dissolved by the mixture of alkali and siliceous earth.

The art of making glass is entirely chemical, as glass is nothing but a combination of fixed alkali with siliceous earth. The purity, the proportion, and the complete fusion of these two substances by a fire sufficiently intense, and kept up for a proper length of time, are the three conditions requisite for the preparation of glass, of a proper transparency, of sufficient hardness, and liable to no alteration from the attacks of air. We shall afterwards learn what other substances are mixed with these two in this composition, in order to render the glass more weighty and transparent, and to communicate to it several other properties which render it fitter for the purposes to which it is applied.

Potash acts not with the same force on aluminous as on siliceous earth: but the phænomena which it exhibits, when applied to it, are not yet well known.

This salt appears to be susceptible of combination with barytes, magnesia, and lime. But its combinations with these substances have not yet been so accurately

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Although potash has never yet been decomposed; yet a number of facts with which the reader shall be hereafter made acquainted, concur to show that it is not a simple substance. Stahl, who considered simple salts as a combination of earth and water, thought that fixed alkali differed from the acids only by containing a greater proportion of earth: and in this manner he accounted for its dryness, &c. Potash, in all probability is a combination of the three preceding earths with the azotic principle. Some analogies lead me to think that it contains lime. But this conjecture is not yet supported by a sufficient number of facts.

Potash is used in surgery to corrode the skin, and produce inflammation and suppuration in certain cases.

Species II. Soda.

THIS saline substance, which exhibits the same general characteristics with the foregoing, has received the name of *mineral fixed alkali*: It is found in abundance, combined with a peculiar acid salt in sea-water, and in some spring-waters: sometimes too it is met with in vegetables, but much seldomer than the foregoing. This salt has been called *marine alkali*, from its making a part of marine salt; and *alkali*, or *salt of soda*, because it is oftenest obtained from that substance. We prefer the simple name of *soda*.

The taste of soda is equally strong and caustic with that of potash. It turns the syrup of violets green, and produces the same alteration as the other on that colour:

lour : it appears naturally in a dry and solid form. It melts in fire as it begins to become red-hot : a violent heat volatilizes it : it acts on almost all the vessels in which it can be exposed to heat.

When exposed to atmospheric air, it attracts its moisture, and the peculiar acid which it contains ; so as to become gradually a neutral salt. The manner in which it is affected by the oxygenous principle and vital air is not yet known.

It dissolves in water with heat, and the disengagement of a fetid lixivious odour. It cannot be obtained pure after this solution but by evaporation in close vessels. The lixivate, when exposed to the air, readily absorbs its acid, and becomes neutral. Therefore, to preserve it pure, it must be kept in close vessels.

Soda readily combines with siliceous earth in the dry way, so as to compose glass. Glass-makers have even observed it to be more fusible, and to adhere more readily and firmly with this earth than potash ; to which they on this account prefer it. And therefore what was said above concerning the use of potash in glass-making, may be applied to soda. Lastly, this alkali, as well as potash, combines with acids and a great many other bodies, as we shall afterwards understand.

After this account of the properties of soda, we must observe, that there is no very remarkable difference between potash and soda when both are in a state of purity. It is only in their combinations that the difference of their natures can be distinguished. When combined with the same acid, they afford neutral salts totally different from each other ; and this is the more surprising, because it is impossible to distinguish the one from the other when they are in a pure caustic state,

as we have here examined them. Bergman adds another distinctive property of these salts which is well worth knowing; they have not the same affinity with acids. Potash has a stronger affinity with these saline substances than soda; and is capable to decompose neutral salts, consisting of combinations of the latter. We shall take farther notice of this when we come to examine secondary or neutral salts.

The composition or intimate nature of soda is equally unknown with that of potash. The same analyses lead me to think that soda, as well as potash, is a combination of an earth with the azotic principle; and that it is the difference of the earthy base which forms the characteristic difference between the two salts. Magnesia is possibly the base of soda, as I have for some years hinted in my lectures, and M. Lorgna has since attempted to prove. But the facts on which this opinion is founded, are not sufficiently exact and numerous to justify our considering it as a certain truth. As to its uses, it is employed in making glass, in preparing soap, &c.

Species III.

WHAT we call *ammoniac* is a salt commonly known by the name of *volatile alkali*. It is distinguished from the two foregoing salts by a keen suffocating smell and a remarkable volatility. This salt, like the fixed alkalis, was not known in a state of purity before the ingenious experiments of Black and Priestley. A certain imperfect neutral salt was mistaken for it, which is solid and crystallized, and possesses indeed some of the properties of volatile alkali, but is really a compound

pound of two saline substances. The property of effervescing with acids, which has been ascribed to volatile alkali, belongs only to that neutral salt, which shall be afterwards described.

That which is known in the laboratory under the name of *caustic*, or *fluor volatile alkali*, and in pharmacy by the name of *volatile spirit of sal ammoniac*, is not pure ammoniac; it is only a solution of ammoniac in water. Dr Priestley has shown, that by the operation of a gentle heat, a permanent gas may be extracted from it; and that the water, when deprived of this gas, gradually loses its alkaline properties. This aeriform fluid is ammoniac, and is known by the name of *ammoniac gas*. This is the body whose properties we must examine, if we wish to know those of genuine *volatile alkali*; as Macquer has very properly observed.

To obtain this elastic fluid, put into a small retort or a glass matrafs a certain quantity of the *alkaline spirit*. Adapt to the retort, or the matrafs, a curved tube or syphon; the extremity of which is to be immersed into a pneumato-chemical machine filled with mercury; so that it may be received under an inverted glass filled with the same fluid. Heat the bottom of the retort or matras with burning charcoal or the flame of spirit of wine. Suffer the first part of the elastic fluid, which is mostly common air from the vessel and the tube, to escape; and as soon as the ebullition becomes strong, collect the gas in the inverted glass. The distillation must not be carried so far as to evaporate the water; or at least the tube which is used should in the middle swell into a bowl that may be kept cool, so as to condense the vapour: the ammoniac gas will then be obtained very dry and pure.

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The gas thus obtained resembles air, and has the same transparency and elasticity. It is rather lighter, however; its smell is more penetrating; and its taste is acrid and caustic. It instantly converts the blue colour of violets, mallows, and radishes, into a deep green, but does not alter it, as the pure fixed alkalis do. It kills animals, and corrodes the skin, if exposed for any time to its contact.

Though it does not serve to maintain combustion, but extinguishes bodies in inflammation, yet it increases before extinguishing the flame of a wax-candle: it renders its bulk somewhat more considerable, and causes it to assume a pale yellow colour round the edge. This fact proves that ammoniac gas is partly inflammable.

Porous bodies, such as charcoal, sponge, &c. absorb it.

Dr Priestley has discovered, that the electric spark, in passing through ammoniac gas, renders its bulk three times greater than before, and disengages from it a portion of hydrogenous gas. The cause of this phenomenon is hitherto unknown; only it appears that the ammoniac is decomposed in this experiment, and that the two matters, of which, as we shall presently show, it is composed, are separated, and pass into the state of elastic fluids.

Ammoniac gas is one of those elastic fluids which heat dilates the most. Atmospheric air does not combine with this gas; it only dilates and divides it. The action of vital air on this fluid has not yet been examined.

Water readily absorbs ammoniac gas: if in the state of ice it immediately melts with cold; but on the contrary, this gas communicates heat to fluid water. Wa-

ter saturated with this gas, or liquid ammoniac, is the substance known by the name of *fluor* and *caustic volatile alkali*. We shall hereafter see that the purest and most concentrated volatile alkali is prepared by receiving the gas into distilled water till the liquid be saturated with it.

Ammoniac gas has no discernible action on earths or salino-terreous substances; but it acts vigorously on acids and a number of neutral salts, as we shall hereafter see. Liquid ammoniac has the same properties as the gas; only it possesses them in a less eminent degree: For the gaseous aggregation being, according to one of the laws of affinity, much weaker than that of liquids; of consequence, ammoniac gas must have a greater tendency to combination than liquid ammoniac.

This salt has been considered as a combination of fixed alkali with a combustible substance. What gave rise to this conjecture was, that, in many instances, fixed alkalis, when heated with inflammable matters, produce ammoniac. But it was not known whether, on such occasions, fixed alkali entered entire into the composition of ammoniac, or only supplied a peculiar principle, which, by combining with part of the combustible matter, formed this salt. The nature of ammoniac is at present somewhat better known. The fine experiment of Dr Priestley, in which he changed alkaline into inflammable gas, by means of the electric spark, has made several chemists suspect this last substance to be one of the principles of ammoniac. M. Berthollet having engaged in a particular series of experiments with a view to determine this, has at length shown ammoniac to be a compound of the

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the hydrogenous and the azotic principles, with a certain quantity of the caloric. He has drawn this induction from observing the action of oxygenated muriatic acid on ammoniac, the decomposition of ammoniacal nitrate in close vessels, and the reduction of metallic oxides by means of ammoniac. Each of these facts shall be particularly examined in our history of the compound substances into which ammoniac enters. Here we will content ourselves with observing, that by heating combinations of the oxides of copper and gold with ammoniac, water and azotic gas are obtained, and the metals are reduced. In such operations the ammoniac is decomposed, and its hydrogen combining with the oxygen of the metallic oxides, forms the water; the metals are left pure, and the azote, the other principle of ammoniac, becoming free, combines with the caloric, and the two are disengaged in azotic gas. Berthollet concludes ammoniac to consist of six parts of azote and one of hydrogen, with a certain quantity of caloric.

Ammoniac diluted in water is administered in a great many diseases. It is aperient, and powerfully incisive. It acts strongly on the skin; it is prescribed as a remedy for the bite of vipers, and for cutaneous and venereal complaints, &c.

As it is acrid and caustic, it is to be very cautiously applied. Externally applied, it is very serviceable in discharging tumours, especially such as are formed by coagulated milk, lymph, &c. I have prescribed it successfully in these cases: it is a ready cure for burnings; and is often successfully applied for chiblain, &c. It has been long used, and under a variety of names, as a most active stimulant in

cases of syncope, apoplexy, &c. But it should be used in very moderate quantities in these latter cases; it is dangerous to administer it internally, unless diluted in a large quantity of water. Alarming excoriations have sometimes been produced on the duct of the œsophagus and the membranes of the stomach, in cases where it has been rashly administered.

C H A P.

ACIDS

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C H A P. IV.

Genus III. *Acids.*

ACIDS are known by their sour taste when diluted in water; they convert blue vegetable colours to red; many of them appear under a gaseous form; they combine rapidly with alkalis; they act much more powerfully than alkalis on combustible bodies, often reducing them to a state of calcination. As inflammable matters, especially metals, are found to contain a considerable quantity of oxygen after they have been exposed to the action of acids, while these again are found to have passed at the same time into a combustible state; from these facts it may be inferred that acids are by no means the simple bodies they were thought to be, but are in general compounds of an inflammable matter, combined with the oxygenous principle.

We are acquainted with ten different species of acids in the mineral kingdom. We find also, in the same division of nature, the phosphoric acid, united with iron, lead, and lime.

The carbonic acid.

The muriatic acid.

The fluoric acid.

The nitric acid.

The sulphuric acid.

The boracic acid.

The molybdic acid.

The tungstic acid.

The arsenic acid.

The succinic acid.

We shall here treat of the first six, which are most plenteous and best known; the other four will be examined elsewhere.

Species I. *The Carbonic Acid.*

WE give the name of the *carbonic acid* to an acid which occurs in great abundance through the whole of nature, and which appearing often in the state of an aeriform fluid, was at first called by the English *fixed air*; afterwards by Messrs Bewly and de Morveau *the mephitic acid*; by Macquer *mephitic gas*; by Bergman *the aerial acid*; and by Bucquet *the cretaceous acid*. The propriety of the denomination which we have adopted will afterwards appear.

This substance was not always thought to be an acid. Its leading properties were observed by Paracelsus, Van Helmont, Hales, &c. But we are indebted to Messrs Black, Priestley, Bewly, Bergman, and the Duke de Chaulnes for our knowledge of its acidity.

The gaseous carbonic acid possesses all the apparent characteristic properties of air. Like air, it is invisible and elastic; and when inclosed in a glass vessel, or floating in the atmosphere, it cannot be certainly distin-

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distinguished from that fluid. It is one of the principles of atmospheric air, but the most scanty in the composition *. It is found perfectly pure in subterraneous cavities, which it entirely fills, as in the *grotto del cane*. It is combined with a great number of natural bodies, such as mineral waters and many neutral salts; spirituous fermentation produces great quantities of it. It is also formed by respiration and the combustion of coals: Lastly, it is constantly exhaled from all parts, and more especially from the leaves, of plants in the shade.

Though this acid, in the state of an elastic fluid, has all the appearance of air, yet it possesses different physical properties; its specific gravity, for instance, is double that of air. Like all other fluids, it may be poured from one vessel into another; it flows from the cock of a wine-cask, after the wine is drawn off; its taste is pungent and subacid; it is instantaneously fatal to animals, because it affords no supply for respiration; it extinguishes flaming tapers, and all bodies in combustion. It communicates to the tincture of turnsol a bright red colour. That colour vanishes gradually in the air as the acid evaporates. It produces no alteration on the colour of violets, as it acts but very feebly on very deep and fixed colours.

This acid has but a very faint tendency to combination;
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* M. Lavoisier's ingenious experiments have led him to consider atmospheric air as a compound of vital air, carbonic acid, and azotic gas, most commonly in the following proportions.

Vital air,	27
Carbonic acid	1
Azotic gas	72
Total	100

tion; the weakest indeed of all bodies of the kind. It suffers no discernible alteration from the contact of light.

Heat dilates it, but produces no change on its nature.

It mixes with vital air without suffering any alteration; and the mixture will maintain respiration as long as the carbonic acid does not exceed a third part of it. On this account, it admits of being used as a remedy in diseases of the lungs.

It combines with water but very slowly. By shaking these two fluids together, so as to bring them as much as possible into contact with one another, they are made to unite and form an acidulous liquor. Bergman gives this solution the name of *aerated water*. But this name belongs more properly to water containing atmospheric air, which it may serve to distinguish from boiled water that has been deprived of its air by heat. The colder water is, the more of the carbonic acid does it dissolve. But there is a point of saturation; even the coldest water cannot absorb a greater quantity than what is equal to its own bulk.

Water saturated with carbonic acid is somewhat heavier than distilled water. Agitation makes it sparkle; it has a pungent, acidulous taste, and reddens the tincture of turnsol. It is decomposable by heat; which soon brings it to a state of ebullition, and disengages the elastic acid. The contact of air produces the same effect more rapidly in proportion as its temperature is higher. Therefore, in order to preserve this acidulous liquor, it must be inclosed in vessels properly stopped, and standing in a cool place, or under strong compression.

This acid solution abounds through nature. Of it

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acidulous and gaseous waters, such as those of Pyrmont, Seltz, &c. consist.

As this acidulated water is a remedy in all putrid disorders, either by drinking or bathing, naturalists have invented an apparatus for impregnating with ease, and with all possible quickness, any quantity of water with as much of the carbonic acid as it can maintain in solution. Dr Priestley, in the year 1772, gave the first account of a process for acidulating water that was offered to the public. Dr Nooth has invented a machine for this purpose, which has been improved by Mr Parker, and still farther improved by Mr Magellan. It is at present to be found in all philosophical laboratories. There is an excellent description, and an engraving of it, in Dr Priestley's Experiments on the different kinds of Air, p. 112 to p. 118; and in Mr Magellan's letter in the same work, vol. v. page 83.

The carbonic acid does not act upon siliceous earth. It is well known that acidulated water alone never crystallizes siliceous earth; a fact which was some years since communicated to the public.

The carbonic acid unites with aluminous earth, barytes, and magnesia. With these substances it forms various neutral salts, which we shall afterwards have occasion to examine.

The combination of this acid with lime dissolved in water, gives rise to an invariable phenomenon, which always indicates the presence of the acid. As soon as it touches the liquid, it produces white clouds, which soon thicken and form a plenteous precipitate. These clouds are owing to the chalk, or carbonate of lime, formed by the combination of lime with the carbonic acid. This new salt not being soluble in pure water, is separated, and subsides to the bottom of the fluid.

Lime

Lime water is therefore a test, by which we may distinguish the nature and the quantity of the acid under examination. If, after this precipitation, more of the acid be added, the precipitate will again be dissolved by the additional quantity of the carbonic acid, and will disappear. Here is a second characteristic by which this acid may be known. The chalk thus dissolved by the addition of a second quantity of the carbonic acid, is again precipitated when the liquor is heated or exposed to the air, or lastly, by all processes which carry off the superfluous quantity of carbonic acid. Thus, I have remarked, that the caustic fixed alkalis and pure ammoniac, when poured into a solution of chalk with the carbonic acid, cause a precipitation by absorbing part of the acid.

Acidulated water, if poured into lime water, produces upon it precisely the same effects.

The carbonic acid combines rapidly with the three alkalis. If a small quantity of pure caustic fixed alkali, in a liquid state, be put into a vessel filled with this acid, obtained from chalk or from beer in a state of fermentation, and the mouth of the vessel be immediately closed with a wet bladder, the bladder will be seen to contract gradually, on account of the vacuum produced in the vessel by the alkali absorbing the carbonic acid. The combination of these two salts is attended with heat; and the sides of the vessel are soon covered with crystals which become gradually larger. This salt is called *carbonate of potash*, or *carbonate of soda*, according as the one or the other of these fixed alkalis is employed. These two genuine neutral salts were formerly called *salt of tartar*, and *salt of soda*. We shall examine their properties in the following chapter.

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Ammoniac gas, and the aeriform carbonic acid, brought into contact in a close vessel, also produce instantaneously a vacuum, heat, and a thick white cloud which forms into regular crystals, or simply into a crust, on the sides of the vessels. This is an imperfect neutral salt, to which we may give the name of *ammoniacal carbonate*; and which was formerly called *concrete volatile alkali, English salt, &c.*

The carbonic acid does not adhere to all of these bases with the same force. According to Bergman, barytes is the substance with which it has the greatest affinity; next in order come lime, potash, soda, magnesia, and ammoniac. We will have occasion in the history of neutral salts to take notice of the facts on which Bergman has established this order of affinities.

The nature and composition of this gaseous acid have for some years much engaged the industry of chemists. Priestley, Cavendish, Bergman, and Scheele, seem to agree in thinking it a compound of vital air with phlogiston. But as the existence of that principle has been with reason questioned by a number of celebrated French chemists, who have urged many difficulties and objections against it, to which no satisfactory answer can be given, we cannot therefore admit of this theory. I once thought that the carbonic acid might be a compound of inflammable gas with pure air: but the discovery of the nature and the decomposition of water renders that conjecture improbable; and M. Lavoisier has supplied in its room a fact supported by demonstrative evidence.

That chemist, to whom the science is indebted for so many ingenious and nice experiments, burnt a certain quantity of charcoal, deprived of all its hydrogenous gas by a previous calcination in close vessels, in

inverted glasses, filled with mercury above a portion of vital air: for he had observed, that if the operation were performed without the precaution of calcining the coal, drops of water would be obtained, and would necessarily render the calculation inaccurate. This operation was performed by means of a quarter of a grain of agaric tinder, placed on a bit of coal, and covered with a very small quantity of phosphorus: a piece of iron wire bent, and made red hot, passed thro' the mercury, so as to kindle the phosphorus; the phosphorus communicated the inflammation to the agaric tinder, which again communicated it to the coal; the inflammation was very rapid, and accompanied with much light. The whole apparatus being cold, M. Lavoisier introduced into the glass a portion of liquid caustic fixed alkali; which absorbing the acid formed during the combustion, left part of the vital air as pure as at the beginning of the experiment. This chemist is of opinion, that in this experiment the oxygenous principle, which by combining with the caloric former vital air, produced a portion of the carbonic acid, by combining with the matter of the coal, while the other principle of the same vital air was disengaged under the form of heat and light. A portion of ashes remained; and the quantity of the acid formed, was equal in weight to the vital air consumed and the weight which the coal had lost. From a number of experiments of this kind, M. Lavoisier concluded, that a quintal of the carbonic acid, the name of which the reader may now perceive to be founded on its nature, consists of about 28 parts of pure carbonaceous matter, and 72 of oxigene.

He thinks, that in the respiration of animals, a real carbonaceous matter is actually disengaged from the blood,

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blood, which, by combining with the oxigene of the atmosphere, forms the carbonic acid, which is constantly produced by respiration; and that in the same manner the carbonic acid, disengaged in spirituous fermentation, is produced by the combination of the carbonaceous matter of sugar with the oxygenous part of water.

Several philosophers have observed, that this acid, in a state of fluid elasticity, possesses the property of preserving animal substances, retarding their putrefaction, and even restoring them to a sound and fresh state after putrefaction has begun to take place. From this fact Macbride has inferred, that the acid unites with the body, thus restoring to it what it lost by putrefaction. This latter phænomenon, in his opinion, is occasioned by the natural decomposition of organic matters, and the dissipation of the carbonic acid they contain, which he calls *fixed air*; and therefore he asserts the use of this acid to be indispensably necessary, in order to afford animals a supply of what they are so constantly losing, and to restore the fluids when altered by motion and heat. He acknowledges the existence of this acid in fresh vegetables, more especially in such as are susceptible of fermentation; as a decoction of barley which has been suffered to germinate, the infusion of raisins, &c. all of which, he thinks, may be with equal propriety prescribed in diseases occasioned by the septic motion of the humours; such as the scurvy.

Water impregnated with the carbonic acid has been also proposed as a remedy in putrid bilious fevers; and has been used with success in a number of instances. The English are said to use the carbonic acid, mixed in a low and unequal proportion with common air, in diseases of the lungs.

It has been strongly recommended as a lithontriptic,
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or solvent of the stone in the bladder. But there is no well authenticated instance of its being successfully used in France against this dreadful distemper. Besides, this is contradictory to what Scheele and Bergman have discovered concerning the stone in the bladder; of which we shall elsewhere speak.

The newspapers have given accounts of a number of cancerous cases cured in England by the use of carbonic acid. But we can assert, that we have often seen it used in such cases, and have even tried it ourselves, still without effect. After the first applications, the cancerous ulcer seems to assume a more favourable aspect; the sanies which usually flows from it becomes white, consistent, and somewhat pure; the flesh assumes a fresh lively colour; but these flattering appearances are fallacious, and do not continue; the ulcer soon returns to its former state, and its progress goes on as before.

The period of the first discovery of this acid by Dr Black is to be considered as one of the most illustrious æras of chemical science. To point out the influence of this discovery upon the science, we shall here offer the following remarks. 1. It has made us acquainted with a peculiar acid. 2. It has explained the cause of the effervescence of the common alkalis, chalk, calcareous spar, and magnesia, when mixed with acids stronger than themselves. 3. It has enabled us to distinguish all alkaline matters as existing in two states, *pure and caustic*, or *soft*, *with the property of causing effervescence*. 4. It has thrown new light on the history of the elective attractions of ammoniac and chalk for the acids. 5. It has furnished us with one of the first instances of an acid preferring lime to the fixed alkalis. 6. The history of places containing mephitic air, caverns which

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which are instantly fatal to the life of animals, is become since this discovery more simple and intelligible. 7. To the former analyses of waters, we have been enabled to add by this discovery an accurate knowledge of gaseous, spirituous, and acidulous waters; so that we can now produce by rule the most perfect imitations of them. 8. It has likewise made us much better acquainted with the solutions of iron contained in various waters; and has taught us how to make up martial waters exactly resembling those of nature. 9. It has made us acquainted with a new class of neutral salts, alkaline and metallic, which have the carbonic acid for one of their principles, and to which we shall therefore give the name of *carbonates* in this work. 10. It has opened a new tract for the researches of naturalist and chemists, and roused that ardour for such pursuits, to which we are indebted for all the fine discoveries which have been made since that period. The name of Black will therefore be famous in the annals of chemistry as long as the science shall be cultivated.

As to the production of this acid by the electric spark passing through vital air, we must observe, that in the experiments of M. Landriani, the iron used as the conductor of the electric fluid, is evidently the cause of the phenomenon by means of the plumbago, &c. which it contains. The trifling quantity of the acid obtained is an unequivocal proof of this.

There are, no doubt, many cases in which the carbonic acid is decomposed and resolved into its principles, as well as other acids: Thus, for instance, water saturated with this acid is much fitter than distilled or common water for the production of vital air on leaves exposed to the rays of the sun: the vegetable substance seems to absorb the carbonaceous matter, while the light, acting

acting like heat, contributes by separating the oxygen to the production of vital air. It is likewise very remarkable, that certain oxides of iron, distilled in a pneumato-chemical machine, afford only carbonic acid as they pass to the state of æthiops or black oxide of iron. This depends either on the carbonaceous matter, or the plumbago contained in several kinds of iron. The carbonaceous matter, by absorbing part of the oxygen of the iron, forms the acid which is disengaged. These newly discovered facts will be explained more at length in some of the following chapters of this work.

Species II. *The Muriatic Acid.*

IN the laboratories, the name of *marine acid*, or *spirit of salt*, or *liquid muriatic acid*, is given to a fluid of the consistency of water, of a taste strong enough to corrode our organs when it is concentrated; but which, when diluted in water, affects the tongue only with a sourness and stipticity. This fluid, when perfectly pure, is absolutely colourless. When it is red, or citron coloured, like the marine salt of the shops, it owes its colour to some combustible substance, frequently to iron, which alters it. This acid is obtained either from marine salt or muriate of soda, as we shall see in the history of that salt. If strong and concentrated, it exhales when exposed to the air a white vapour or smoke. It has a lively penetrating smell, which when faint or much diluted, resembles the smell of citrons, or the apple called the *golden rennet*. It is then called the *fuming muriatic acid*. Its vapour rises most copiously when the air is moist. If, on opening

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a flask full of this acid, you put your hand to its orifice, you feel a sensible heat; which is occasioned by the combination of the acid in the state of vapour with the water of the atmosphere.

The muriatic acid communicates a deep red to the syrup of violets, and all blue vegetable colours, but does not absolutely destroy them. This liquor, however concentrated and fuming, is not muriatic acid in a pure and separate state; but muriatic acid combined with a considerable quantity of water. Dr Priestley has established this truth beyond a doubt, by showing that this acid may be reduced to a gas, and rendered permanent in that state, over a portion of mercury, by the temperature and pressure of the atmosphere: it is therefore the properties of this gas we must examine, if we wish to acquire a knowledge of those of the muriatic acid, unmixed and in a state of purity.

The muriatic acid gas is obtained by heating the liquid fuming acid in a retort, the extremity of which enters a bell-glass full of mercury. The gas being much more volatile than the water, passes through the retort into the glass; it displays all the apparent properties of common air, but is more ponderous. It has a keen penetrating odour; and is so caustic that it inflames the skin, and often occasions violent itchings. It suffocates animals, and extinguishes the flame of a taper, after magnifying it and causing it to assume a green or bluish flame round its edge. Spongy bodies absorb this acid.

Light does not appear to alter it in any sensible degree. Heat rarefies it, and increases its elasticity amazingly. Atmospheric air, mixed under bell-glasses with muriatic gas, causes it to assume a fummy or va-

porous form, and is gently heated ; from which it appears that a combination actually takes place. When the air is humid, these vapours are more discernible : M. d'Arcet has observed that they are not perceptible on the tops of high hills, where the air is very dry. The white vapours exhaled by the muriatic acid gas are therefore owing to the water contained in the atmosphere. Neither the liquid acid nor the gas absorbs vital air in a state of elasticity, in any sensible degree ; yet some properties, which we shall mention by and by, enable them to combine with the oxygenous principle. It is asserted that the liquid muriatic acid may be caused to absorb a portion of vital air, by shaking them violently together.

The muriatic acid gas combines rapidly with water. Ice, on coming into contact with it, instantly melts to absorb it. Water uniting with this gas acquires a considerable heat. When saturated with it, it cools and becomes the same with the liquid acid from which the gas was obtained ; it exhales white vapours, is colourless, reddens syrup of violets, &c. We shall afterwards see, that the most concentrated and pure liquid muriatic acid is obtained by saturating pure water with the elastic fluid.

The muriatic acid gas has no power of action on siliceous earth ; it combines with aluminous earth, and by that combination forms aluminous muriate.

It unites with the saline-terreous substances, forming in combination with them barytic, the magnesian, and calcareous muriates.

Its combination with potash is *the febrifuge salt of Sylvius*, or muriate of potash : with mineral alkali or soda, it gives marine salt, common salt, or muriate of soda.

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The muriatic gas when brought into contact with the ammoniac gas, acquires a considerable heat. The two elastic fluids penetrate each other, a white cloud instantly rises, the mercury is elevated in the glasses, and the sides of the glasses are soon covered over with ramified crystals, which are sal ammoniac, or ammoniacal muriate. If the two gases are very pure, they disappear entirely when the concretions are formed, and the heat disengaged. This experiment among others proves, 1. That bodies which pass from a liquid to a solid state, absorb in their transition a certain quantity of the caloric principle, or the matter of heat; for the cause which converts the muriatic acid into a gas, is its receiving an additional quantity of heat. 2. That the heat absorbed by elastic fluids, in their *aerification*, is disengaged when they return to a liquid or solid state. 3. That the elasticity of fluids is produced by their absorbing and combining with heat; and that all aeriform fluids are compound bodies, which owe their form to fixed heat, or the caloric principle, as we have elsewhere shown.

The muriatic acid absorbs the carbonic acid; but the reciprocal action of these two acids has not yet been properly examined. The muriatic is known to be the stronger of the two; for it disengages the carbonic from all its bases, and enters itself into combination with them. Bergman arranges its attractions for the different alkaline bases in the following order, proceeding from that with which it has the strongest to that with which it has the weakest affinity: barytes, potash, soda, lime, magnesia, ammoniac, aluminous earth.

The intimate nature of the muriatic acid, and the principles of its composition, are unknown. Beccher imagined it to consist of sulphuric acid with *mercu-*

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rial earth; because he had observed that acid to have a strong affinity, and combine very readily, with all the bodies in which he admitted the existence of this principle, such as arsenic, mercury, &c. Stahl has not illustrated Beccher's opinion concerning this acid. And among all the ingenious experiments of the moderns, there is none which throws any light on the constituent principles of the muriatic acid. As its base is unknown to us, we cannot determine whether it admits of two states of saturation with oxigene; in one of which, the base being completely saturated, the acid must be stronger, while in the other the base being combined with a smaller quantity of oxigene, the acid must be weaker, according to what has been observed of the nitric, the nitrous, the sulphuric, and the sulphureous acids. Even the existence of oxigene in the muriatic acid has not yet been fully evinced; it is only from analogy that it has been admitted.

Scheele is the only chemist who has done any thing of consequence on this head. In the year 1774, he made an important discovery concerning the different states in which this acid exists. By distilling a quantity of muriatic acid upon oxide of manganese, he obtained this acid in the form of a yellowish gas, of a very pungent smell, amazingly expansive, and capable of dissolving any metal with facility, mercury or gold not excepted. He thought that, in this instance, the manganese, which he imagined to be very greedy of phlogiston, absorbed the phlogiston of the muriatic acid; and he therefore called this acid, after it had undergone this operation, *dephlogisticated marine acid*; and thought that it dissolved gold from its avidity to unite with a new portion of phlogiston. No unequivocal experiment, however, demonstrated the existence of the inflammable principle in this acid: and

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in the year 1780, I suspected that it was the base of vital air contained in the manganese, which entered into union with the muriatic acid; as may be seen in the first edition of my Elements under the articles *Aqua Regia* and *Manganese*, &c. M. Berthollet, my fellow-academician, has shown that conjecture to be a certain truth, by a series of accurate and ingenious experiments.

A distillation of the muriatic acid on oxide of manganese, afforded him yellow vapours without the help of fire. If the retort be heated, and the vapours received in flasks full of water, and immersed in ice, a very small portion of the acid is dissolved, but the water is soon saturated; after the saturation of the water, the rest of the gas assumes a concrete form, and falls in crystals to the bottom of the liquor. This salt melts, and rises in bubbles with the most moderate heat.

The oxygenated muriatic acid in a liquid form, or dissolved in water, has, according to M. Berthollet, an harsh though not an acid taste; it whitens and destroys vegetable colours, without changing them first into a red; it neither expels the carbonic acid from its bases, nor produces any effervescence with alkaline substances saturated with that acid; in short, it possesses not the usual properties of acids. If heated with quicklime, it effervesces, and gives out vital air, so that the remains is nothing but calcareous muriate; which is evidently produced by the disengagement of the oxigene with which the acid was saturated. The oxygenated muriatic acid produces likewise an effervescence when it combines with pure ammoniac. The result of this combination is, on the one hand, water; on the other, azotic gas. In this instance, the oxygenated muriatic acid and ammoniac are both decomposed; the hydrogen, which is

one of the principles of the ammoniac, unites with the oxigene, with which the muriatic acid is super-saturated, and by their union the water is formed; while again, the azote, the other principle of the ammoniac, uniting with the caloric, escapes under an elastic form, and produces the effervescent motion observed in this experiment. Lastly, the oxigenated muriatic acid converts metals into oxides, and dissolves them without occasioning effervescence. It destroys vegetable colours, as it passes into the state of common muriatic acid. All these experiments prove, that Scheele's dephlogisticated muriatic acid, is a combination of this acid in a pure state, with the base of vital air, or the oxigenous principle; and that its proper name is, *aerated or oxigenated muriatic acid*, as I have shown in my first edition. M. Berthollet has not yet determined what quantity of oxigene the muriatic acid must absorb, in order to acquire the properties of oxigenated muriatic acid *. In March 1787, he discovered that oxigenated muriatic gas, received into a lixivate of caustic potash, forms a crystallizable neutral salt, which, like nitre, or even in a greater degree, produces detonation on burning coals; affording by the action of the fire very pure vital air, or oxigenous gas, and leaving a residue of the muriate of potash. These experiments concur to support the theory which I offered to the public seven years since, concerning the nature of the oxigenated muriatic acid; for the detonation of oxigenated muriate of potash is plainly owing to its containing an extraordinary quantity of oxigene. Soda forms only a deliquescent salt with the oxigenated muriatic acid.

The muriatic acid is made use of in several of the arts,

* See *Journ. de Physique*, tome xxvi. page 321, Mai 1785.

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arts, and more especially in the art of assaying in the humid way *. In medicine, it is well diluted in water, and administered as a diuretic, an antiseptic, and a cooler; it is the chief ingredient of the Prior de Chabrieres cure for ruptures. It is externally applied as an escharotic, to destroy altered flesh, as a cure for the gangrene in the throat, aphthæ, &c. Mixed with a certain quantity of water, it composes a bath for the feet, used by some people, and considered as a secret, for drawing the gout from the more vital to the inferior parts.

But the oxygenated muriatic acid has been known for too short a space of time to admit of its being much used in the arts. M. Berthollet thinks that it may be successfully employed for discovering in a few minutes or hours, what effects the action of air would produce on coloured stuffs, and thus determining the fixity or alterability of the colours: he has of late recommended it for whitening linen and unbleached yarn: and the first trials, which have been in Paris on a pretty extensive scale, promise favourably. It may likewise be advantageously employed for whitening in a short time the yellow, and more especially the green wax from our islands.

Species III. *The Fluoric Acid.*

THE fluoric acid, discovered by Scheele, has received this name because it is obtained from a sort of earthy neutral salt, with which we shall afterwards get acquainted under the name of *fluor spar*.

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* See Bergman, de Docimasia humida, Opusc. Vol. II. &c. Or the English translation of his *Opuscula*.

This acid when pure has a gaseous form, and we must examine its properties as it exists in that state. The fluoric acid is more ponderous than common air. It extinguishes lights and kills animals. It has a pungent penetrating smell, nearly the same with that of the muriatic acid gas, but rather less keen. Its causticity is such that it corrodes the skin, however short the space of time during which it is exposed to its contact. It suffers no sensible alteration from light. Heat dilates it, but without changing its nature.

The water contained in atmospheric air enables it to destroy the transparency of the fluoric acid, and convert it into a white vapour; which it does more or less readily, according as it contains a greater or a less quantity of water. This phenomenon resembles that which the muriatic acid presents on the same occasion; but the smoke of the fluoric gas is thicker than that of the other.

The fluoric acid gas unites eagerly with water, and heat is produced at the instant of their union. A peculiar phenomenon appears on this occasion, namely, the precipitation of a very fine white earth, which appears to be siliceous earth. From this circumstance it appears that the acid is far from being pure in the state of elastic fluidity. It becomes pure, therefore, only when the earth, which adhered to it when it was volatilized, has been separated by the action of water. A solution of this gas in water constitutes the acid spirit of luor; the smell and causticity of which are very strong when the water is saturated with it. This liquid acid communicates a strong red colour to the syrup of violets. According to Scheele and Bergman, it possesses the singular property of dissolving siliceous earth. Although the fluoric acid gas, on uniting with water,

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ter, deposits a considerable quantity of this earth, yet it still retains so much that alkalis cause it to afford a new precipitate.

Dr Priestley observed, that the fluoric acid gas corroded and penetrated common glass, and found it necessary to use thick glass bottles for his experiments. Macquer thought that the acid produced this effect only when in a gaseous state, but was incapable of attacking glass when liquid or diluted in water. This opinion is founded on the circumstance of water's precipitating the siliceous earth, which is maintained in a state of solution in the fluoric gas. But it is to be remembered, that the water does not entirely separate the earth from the acid; and therefore the fluoric acid must retain, even in a fluid state, the power of acting on glass and siliceous stones.

The liquid fluoric acid may be decomposed like spirit of salt by heating it in a retort, the extremity of which enters a bell-glass full of mercury. By this means the acid is obtained in gas, and leaves the water pure.

The two French chemists who, in the year 1773, published, under the name of M. Boullanger, a series of experiments on the vitreous spar, or the sparry fluor, are of opinion that the acid of this spar is nothing but a combination of muriatic acid with an earthy matter, which water only is capable of separating from it. But Scheele has successfully combated this opinion. He considers it as a peculiar acid, strikingly distinguished from all others by the various combinations of which it is susceptible. And his opinion is at present very generally received among chemists.

The fluoric is the only mineral acid capable of dissolving siliceous earth. Bergman and Scheele were of opinion,

opinion, in the year 1779, that this earth might very probably be a compound of the fluoric acid with water; because the fluoric acid gas deposits no small quantity of siliceous earth, when brought into contact with water. But an experiment of M. Meyer's has since proved, that the earth precipitated on that occasion comes from the glass vessel, part of which is dissolved by the acid. That chemist took three cylindrical tin vessels, into each of which he put an ounce of *vitreous spar* and three ounces of sulphuric acid, which having a greater affinity than the fluoric acid with lime, is successfully employed to separate this latter acid: to one of these mixtures he added an ounce of pulverized quartz; to the second an ounce of powder of glass; the third he left pure without any addition: in each of the cylinders he hung a wet sponge, and closing up the vessels, exposed them to a moderate temperature. Half an hour after, he found a siliceous dust deposited on the sponge of the mixture containing the glass; at the end of twelve hours, the sponge of the vessel containing the quartz was likewise covered over with an earthy incrustation; but even after several days the sponge of the third vessel exhibited no such appearance. Bergman sent an account of this experiment to M. de Morveau, letting him know at the same time, that he now gave up his opinion concerning the formation of siliceous earth by the combination of the fluoric acid gas with water. The precipitation is therefore owing to the glass dissolved by the fluoric acid gas; and the acid is not pure till after the precipitate has been separated from it by water and alkalis.

The fluoric acid, either in a gaseous or a liquid state, unites with aluminous earth, forming with

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aluminous fluuate *, a sweet tasted neutral salt, which readily assumes the consistency of a thick jelly.

It combines also with barytes: the salt resulting from that combination, to which we give the name of *barytic fluuate*, is a pulverulent substance.

With magnesia the fluoric acid forms a crystallizable salt, *magnesian fluuate*.

It forms a precipitate with lime-water, producing instantly *calcareous fluuate*.

It combines with potash to form *fluuate of potash*; with soda, it produces *fluuate of soda*; lastly, combining with ammoniac, it forms the salt which we call *ammoniacal fluuate*.

This short account of these saline combinations shows the fluoric acid to be evidently different from the muriatic. Its affinities with the different bases afford new proofs in support of the same truth. Bergman observes, that the fluoric acid, when united with potash, may be separated from it by lime-water, which causes the solution of that salt to afford a precipitate. The same thing takes place on a solution of the barytic fluuate, which becomes muddy when lime is put into it. Bergman gives its elective attractions in the following order; lime, barytes, magnesia, potash, soda, ammoniac: But he confesses that more experiments are necessary to establish fully this order of affinities.

The fluoric acid gas has not as yet been applied to any purpose in the arts: but its power of dissolving siliceous earth will in all probability render it very useful in chemical operations, when once processes for obtaining

* According to the methodical nomenclature which we have proposed, the word *fluorate* is here to be used; but we abridge it into *fluuate*: and we shall do the same for the sulphuric acid, using *sulphate* instead of *sulphurate*. A.

taining it more conveniently than at present shall be introduced.

Species IV, *The Nitric Acid.*

WHAT is called *spirit of nitre* in the laboratory, is a combination of this acid with water. In a liquid state and pure, the acid is white; but if altered in the smallest degree, it becomes yellow or red; and there arises from it in great abundance a vapour of the same colour. It is so caustic that it burns and destroys instantaneously the organization of the muscles. It reddens syrup of violets, and entirely destroys its colour.

On being exposed to the rays of the sun, it acquires, according to Scheele, an higher colour and greater volatility; and from this it appears that light acts upon it: As it acquires a deeper colour, vital air is disengaged from it.

Heat volatilizes this acid, and separates the colouring matter in the form of red vapours.

When red, it unites eagerly with water, which assumes, in consequence, a green or blue colour: it appears to have acquired a considerable degree of heat in entering into this combination. When united with a large quantity of the fluid, it forms *aquafortis*.

The white and the red nitrous acids were formerly considered as being of the same substance, only concentrated in different degrees; the strongest coloured was thought to be the most concentrated of the two. But we are now better acquainted with the nature of this saline substance, and know it to be capable of existing in two different states. In one of these the acid of nitre

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is destitute of colour, more ponderous, and less volatile, and emits only a white smoke; in the other, it is of a colour varying in shade from a yellow to a brown red, is more light and volatile, and is constantly emitting red vapours, in greater or less abundance, according to the temperature to which it is exposed. Bergman distinguishes between these two states of the acid of nitre, by giving to the one the name of *dephlogistated*, to the other that of *phlogistated*; we give to the former, the white, the name of the *nitric acid*; to the coloured, the name of the *nitrous acid*. The cause of these distinctions will hereafter be shown: Only, we may here observe, that if the coloured and fuming nitrous acid be distilled in a glass retort, the red part goes first off in vapour, and what remains is a white and colourless acid. The deeper the colour of the spirit of nitre subjected to distillation, so much the greater is the quantity of the vapours obtained, and so much the less the portion of white acid remaining in the retort; and *vice versa*, when the nitrous acid heated in the retort is of a bright red colour, very little vapour, but a great deal of the white acid is obtained. This instance shows the red acid to be more volatile than the white. And as all coloured spirit of nitre is compounded of the two, they are to be separated by a process of distillation judiciously conducted. In this operation a certain quantity of vital air is always disengaged, which may be collected by applying a pneumatocchemical machine to a balloon. We must remark, that when the vessels are red-hot, certain red vapours are constantly separated even from the whitest nitric acid; and the colour of the acid is also changed, so that it becomes of a flame red: But the change produced by heat immediately disappears when the acid returns to its

its former temperature, and the vapour also returns to a liquid. The same thing happens when a portion of the nitrous acid, highly coloured, is united with water; a red vapour is disengaged and passes into the atmosphere; the heat which then takes place, increases the colour of the acid which had been weakened by the water; what remains after the evaporation is not nitrous, but nitric acid; and the change is instantaneous. When heat, by the assistance of light, produces this change on the nitric acid, a quantity of vital air or oxygenous gas is disengaged, proportioned to that of the nitrous gas which is formed on the occasion. This decomposition of the nitric acid, and the change of it into the nitrous, takes place in consequence of the mutual affinities between light, the caloric, and the oxygenous principles. In this instance the glowing heat of our vessels acts like that of the rays of the sun.

The nitric acid acts not upon filiceous earth: it combines with barytes, with magnesia, with lime, and with the three alkalis: with these substances it forms the aluminous, barytic, magnesian, and calcareous nitrates, nitrate of potash, nitrate of soda, and ammoniacal nitrate. All of these salts shall be hereafter particularly examined. The salts formed by the union of the same bases with the nitrous acid are somewhat different from these, and are distinguished in our methodical nomenclature by the name of *nitrites*.

The nitric unites with the carbonic acid, absorbing it eagerly. The mutual action of these two bodies is not yet well known.

The nitric enters very rapidly into combination with the muriatic acid. The alchemists gave the name of *aqua regia* to this compound, because they used it to

dissolve gold, the king of metals: we shall henceforth call it the *nitro-muriatic acid*. It must have always appeared singular, that two acids, neither of which is by itself capable of acting upon gold, should by combination acquire the power of dissolving it. The alchemists, content with having found a solvent for that precious metal, gave themselves no concern about the cause of the phenomenon. It is but a few years since two Swedish chemists, Scheele and Bergman, first sought to discover what alterations the nitric and the muriatic acids produced on each other by mutual combination. Scheele observed, what we have already taken notice of, that by distilling a portion of muriatic acid on lime or oxide of manganese, the acid was caused to diffuse a yellowish vapour of the same smell with *aqua regia*, which destroyed blue vegetable colours, and acted with a powerful force upon metals,—more especially upon gold, which it dissolved as well as the nitro-muriatic acid. He thought that it acquired these properties in consequence of being deprived of its phlogiston by the oxide of manganese, and that what caused it to act so forcibly on combustible bodies was its eagerness to regain the principle which it had lost. For this reason he gave it the name of *dephlogisticated marine acid*. Our first observation here is, that this explanation of these phenomena is directly contradictory to the theory of Stahl, which Scheele generally appears to have adopted and extended: for the muriatic acid is said to acquire, by the loss of its phlogiston, a set of properties which Stahl attributed to the presence of that principle; namely volatility, strong smell, and a power of acting on inflammable matters. Besides, we are of opinion, that all of these phenomena may be much more satisfactorily explained

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ed by the new theory : and this we shall very soon show.

Bergman thinks that the nitric acid seizing on the phlogiston of the muriatic acid, is partly dissipated into vapour, and that what remains of the muriatic acid is then precisely in the same state with the vapour which arises from the distillation of this acid on oxide of manganese. Thus, what enables the nitro-muriatic acid to dissolve gold, is its containing a portion of *dephlogisticated marine acid* : and this mixed acid is often nothing but marine acid. Such is the opinion of the celebrated chemist of Upsal. The following appears to me a better account of the facts. When a quantity of nitric acid is poured upon a quantity of muriatic acid, heat is excited between the two liquors, and they assume a colour ; an effervescence takes place, and a kind of mixed smell arises, not so pungent as that of the muriatic acid, but quite peculiar, and resembling that which this acid affords when distilled on oxide of manganese. Mr Berthollet has discovered, that a portion of oxygenated muriatic acid is disengaged during this rapid re-action of the two acids. On this occasion, therefore, the muriatic acid deprives the nitric of part of its oxygen, and is dissipated in the form of oxygenated muriatic gas ; yet a portion of it still remains saturated with oxygen and nitrous gas ; and this mixture is *aqua regia*. From this we understand why so small a proportion of the nitric acid is necessary to communicate to the muriatic the properties of *aqua regia* ; and why both the nitro-muriate of gold, and the nitro-muriatic acid, afford when distilled nothing but muriatic acid. But we must observe, that, as much more nitric acid than is necessary, is generally used to super-saturate the muriatic acid with oxygen,

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the nitro-muriatic acid which results from this composition contains both acids, and they act each according to its peculiar nature, forming peculiar and distinct salts with all the bodies exposed to their action. It would therefore be a service of some importance to chemistry, to determine what quantity of the nitric acid is necessary to saturate a given quantity of the muriatic with oxygen, and cause it to assume the character of the nitro-muriatic acid, without containing any aquafortis, which only alters it and renders its effects uncertain. Hence it appears necessary, in recording accurate chemical experiments, to mention the proportion in which the two acids have been mixed to produce the *aqua regia* made use of.

This mixed acid has less specific gravity than either of the two acids of which it is composed. It has a peculiar smell, commonly a citron colour, often inclining to orange. Its action on natural bodies distinguishes it from all other acids. Light extricates from it a portion of oxygenous gas or vital air. Heat separates from it oxygenated muriatic acid. *Aqua regia* combines with water in any proportion, and always excites heat as it enters into combination with that fluid. It dissolves aluminous earth, but very slowly: it unites with barytes, magnesia, lime, and the alkalis; and from these combinations there result mixed salts, which crystallize either separately or together, according as they are more or less soluble. *Aqua regia* is much used both in chemistry and in the art of assaying; as we shall show more at large when we come to speak of metallic substances.

Since the æra of Dr Priestley's discoveries, chemists have laboured much to discover the intimate nature and the component principles of the nitric acid. It

was shown, in the first place, that the opinion which ascribed the formation of the nitric to the sulphuric acid, and represented the former as a modification of the latter, was founded on fallacious experiments. Soon after, it was observed, that this acid is formed of peculiar principles; and the following observations led to a certain discovery of its nature.

The nitric acid had been long observed to act with great force on combustible bodies, more especially on the metals. On such occasions, it exhales into the atmosphere a considerable quantity of red vapours, and is often indeed entirely dissipated under that form. The combustible body exposed to its action is soon reduced to the state of a burnt body, or oxide; nay, it often causes combustible bodies, such as oils, charcoal, sulphur, phosphorus, and several of the metals, to emit a sudden flame. Stahl ascribed this effect to the rapidity with which the acid combined with the phlogiston of combustible bodies. But that theory did not afford a satisfactory explanation of the phenomenon.

Dr Priestley, by receiving into a glass vessel filled with water the vapour disengaged during the action of the nitric acid on a piece of iron, observed, that instead of a red vaporous fluid, a transparent colourless gas resembling air was obtained on that occasion; and to this he gave the name of *nitrous gas*.

This gas possesses all the apparent properties of air but differs greatly from it in respect to chemical properties. It has rather less gravity, is unfit for maintaining either combustion or respiration, is strongly antiseptic, has no sensible taste, and takes a long time to alter the colour of syrup of violets. Nitrous gas appears to suffer no alteration from light. Heat dilates it. Vital air readily combines with it; thus re-

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ducing it to the state of nitrous acid. Atmospheric air produces the same effect upon it, but not so forcibly. This combination displays several phenomena which well merit our attention. As soon as air comes into contact with nitrous gas, though both the fluids were before colourless, they become instantly red like the nitrous acid: a pretty lively heat is then excited; the water rising in the receiver absorbs all these red vapours, and thus acquires the character of aquafortis. The purer the air is, the more readily do these phenomena take place, the more striking do they appear, and the smaller is the proportion necessary to change a given quantity of nitrous gas into nitrous acid. M. Lavoisier has discovered, that sixteen parts of atmospheric air are necessary to saturate seven and one-third of nitrous gas, while four parts of vital air are sufficient for the complete saturation of the same quantity of the same gas. Macquer thought this beautiful phenomenon precisely similar to combustion. It is in fact accompanied with heat, the absorption of air, and the production of a saline matter; and the red colour which then appears may be considered as a kind of flame.

As in this artificial composition of the nitrous acid, the air produces different effects, according as it is more or less pure, Dr Priestley thinks that nitrous gas may serve as a test to enable us to distinguish what quantity of vital air any other kind of air contains; if we assume as two terms,—the most impure air, or gas unfit for respiration, such as the carbonic acid, which produces no change whatever on nitrous gas,—and vital air, which produces the greatest alteration upon it. This assay consists in employing known and proportional quantities of these two gases, and observing when

they are mutually and completely saturated. That air is the purest of which the smallest quantity is sufficient to saturate a given quantity of the nitrous acid, and *vice versa*.

Several philosophers have endeavoured to find means for performing this experiment with the most rigid accuracy. The Abbé Fontana has been the most successful: he has contrived an *eudiometer*, of which an exact description is to be found in M. Ingenhoufz's experiments on vegetables. By means of that instrument, the degrees of the purity or impurity of the air may be estimated with the utmost nicety; but, as the author himself acknowledges, such skill and attention are necessary in making use of it, that to avoid mistakes and erroneous calculations is exceedingly difficult.

It is farther of consequence to observe, that these experiments, though extremely ingenious and of considerable utility, have not been attended with all the advantages expected from them, in regard to that branch of medicine, the object of which is the preservation of health. They show what quantity of air fit for respiration is contained in that under examination; but they afford no information concerning the manner in which the noxious qualities of this fluid affect the several parts of the human system with which it is brought into contact by respiration: they explain not how it acts on the stomach, the skin, or the nerves; all of which are affected by almost every alteration of the air, though only medical observation can inform us in what manner.

Chemists have for a number of years been divided in their opinions concerning the cause of the production of the nitrous acid from the mixture of nitrous

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gas with vital air. Dr Priestley, the discoverer of the fact, is of opinion, that nitrous gas is merely nitrous acid super-saturated with phlogiston; and that as pure air has a greater affinity than the acid with phlogiston, it therefore, entering into combination with it, leaves the nitrous acid in a state of liberty. But this theory is far from affording a complete explanation of the phenomenon: for when the elastic fluids with which the experiment is performed are very pure, there is absolutely no residue left; and besides, the nitrous acid formed during the process weighs considerably more than the portion of nitrous gas which was made use of to produce it.

M. Lavoisier imagined that this property of nitrous gas—to produce nitrous acid when brought into contact with vital air, might lead him to a knowledge of the component principles of the acid. By combining two ounces of spirit of nitre, of known strength, with a given quantity of mercury, he obtained 196 cubic inches of nitrous gas, and 246 cubic inches of vital air. While the former gas was disengaged, the mercury changed its form; after the vital air was disengaged, it returned to a metallic state, when it was found to have suffered no loss. From these facts he deduced the following inferences with great accuracy of reasoning.—1. As the mercury suffered no loss during the process, the formation of the elastic fluids cannot be ascribed to it. 2. These must therefore have been formed by the decomposition of the nitrous acid. 3. The nitrous acid made use of on the occasion, the gravity of which was to that of distilled water as 131,607 to 100,000, appears therefore to have been formed of three principles, nitrous gas, vital air, and water, united in the following proportions to the pound: nitrous

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gas, 1 ounce $51\frac{1}{2}$ grains; of vital air, 1 ounce 7 drams 2 grains; and of water, 13 ounces and 18 grains.

4. Nitrous gas is nitrous acid deprived of its oxigene or vital air. 5. In all processes in which nitrous gas is obtained, the nitric acid is decomposed, and its oxigene absorbed, by the combustible body with which it has a greater affinity.

Yet this opinion is attended with one difficulty. M. Lavoisier found that he could not reproduce by the reunion of these products the whole quantity of the acid from which they were obtained; at least one half was entirely lost: and he had much more pure air than was necessary for the complete saturation of the nitrous gas. He acknowledges himself unable to account for this circumstance. Macquer imagined it to depend on the loss of the phlogiston, or light, which he considered as one of the principles of the nitric acid: this he thought might escape through the pores of the vessels during the decomposition of the acid, leaving behind part of its pure air, which being less subtle, could not make its way out with the same facility. We shall soon see this not to be the true cause of the phenomenon.

The portion of superfluous gas which remains after the nitrous gas has been saturated with vital air, still remained an objection against M. Lavoisier's theory. And though this superfluity was quite a trifle in this experiment, as $7\frac{1}{2}$ parts of nitrous gas, with 4 parts of vital air, left no more than $\frac{1}{14}$ th of their total bulk; yet still he was at a loss how to account for it. Indeed he has since informed us, that the residue was much less when the matters made use of were very pure and very nicely proportioned. In short, we will immediately see that vital air and nitrous gas may be obtained

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No such difficulty occurs in considering the aeriform residue formed by the combination of 16 parts of atmospheric air with 7½ of nitrous gas: we know it to be the mephitic or azotic gas contained in the atmospheric air. We understand likewise how the contact of water comes at length to alter nitrous gas and change it into an acid: it is by means of the air which it contains.

But even after this theory of M. Lavoisier's, the nature of the nitrous gas still remained unknown; and it has since been explained by a fine experiment of Mr Cavendish's. That chemist put into a glass tube seven parts of vital air not obtained from the nitric acid, with three of azotic gas or atmospheric mephitic; and by causing the electric spark to pass through the mixture, he effected a great diminution of its bulk, and even changed it into nitric acid. The induction which he draws from these facts is, that the nitric acid is a combination of seven parts of vital air to three of azotic gas; and that, when deprived of a part of the first of these principles, as happens in the solution of metals, &c. it passes into the state of nitrous gas: Nitrous gas, therefore, is, in his opinion, nothing more than a combination of azotic gas with a smaller proportion of vital air than what is requisite to form nitrous acid. These experiments, and the ingenious theory founded upon them, throw great light on the formation of the nitric acid by the putrefaction of animal matters. We know that a great quantity of azotic gas is disengaged from these matters when putrefying; and it is evident how necessary air is for the production of this acid, as

experience shows it to be formed by the combination and fixation of these two elastic fluids.

It is also easy to determine the difference between the pure white acid of nitre and the coloured fuming acid to which the northern chemists give the name of *phlogisticated*; or between the nitric and the nitrous acids. The last is found where the principles are not combined in the proportion proper for forming the pure nitric acid,—that is, when the combination consists not of three parts of the azotic and seven of the oxygenous principle. But as a variety of circumstances, and in general all phlogisticating processes, diminish the proportion of the oxygen by wasting more or less of it, hence we may naturally infer, 1. That this acid is very liable to alteration, and must often be more or less coloured and fuming; 2. That in proportion as it is deprived of more or less of its oxygen, it may pass through many states, from that of the purest nitric acid, which contains the greatest proportion of oxygen, to nitrous gas, which contains not enough to constitute it an acid: 3. That if nitrous gas be deprived of what oxygen remains in it, it becomes azotic gas or mephitic: 4. That as the mutual adhesion of the oxygenous and azotic principles is very trifling, most combustible bodies having a greater affinity with the former than the azotic principle has, the nitric acid cannot but be decomposed with great facility by many bodies. These four remarkable particulars in the history of the acid of nitre, serve to explain a great many phenomena. We now understand, 1. That in this acid the azotic gas and vital air have lost much of their caloric, and are therefore reduced to azote and oxygen. 2. That when this acid is decomposed by a combustible body, the nitrous gas then disengaged does not require

so much caloric to maintain it in a state of elastic fluidity, as vital air and azotic gas. 3. That these two fluids cannot combine when in a gaseous state. 4. That of consequence the vital air obtained from nitrous preparations strongly heated, such as *red precipitate*, nitrate of lead, common nitre, &c. must contain a certain portion of mephitic or azotic gas; of which gas, the residue, remaining after the union of the vital air with the nitrous gas, consists. No such residue is ever observed to remain, when the vital air made use of has been obtained from the leaves of vegetables or from manganese. 5. That the case is sometimes the same with nitrous gas; it may contain a portion of azotic gas or mephitic: and this happens when this gas is prepared with bodies which, being very greedy of oxygen, absorb it almost entirely from the nitric acid; such as iron, oils, &c. 6. That the nitrous acid when coloured, and containing an excess of nitrous gas or of azote, or the base of mephitic, is in a state very different from that in which the two principles are no more than mutually saturated; and that as the difference between these two states of this acid is so very considerable, they should therefore be distinguished by different names. To the white acid, which, though the most uncommon, is the purest, we give the name of the *nitric acid*, observing the same analogy in this as in the rest of our new denominations; and to its neutral salts we give the name of *nitrates*. The red again we call *the nitrous acid*, and its saline combinations *nitrites*. There is indeed but seldom occasion to speak of the last of these classes of neutral salts: for though the red and fuming, or the nitrous, be the most common of the two acids, it very seldom retains its proper character when united with alkaline bases; the

the superfluous quantity of the nitrous gas usually escapes as the combination is taking place, and what remains is pure nitric acid.

The affinities of the nitric acid with the alkaline bases, are the same as those of the muriatic; and Bergman arranges them in the same order, as follows, — barytes, potash, soda, lime, magnesia, ammoniac, aluminous earth. According to that celebrated chemist, the nitrous or *phlogisticated* acid has the same affinities as the pure acid of nitre. It is stronger than any of the preceding acids, and disengages the carbonic, fluoric, and muriatic acids, from their bases.

The acid of nitre, under the name of *aqua fortis*, is applied to a great many purposes in the arts; more particularly, it is used to dissolve mercury, copper, silver for hatters, engravers, and gilders, in assaying and working metals, &c. It is likewise used in surgery, to destroy warts and other little indolent uninfamed tumours. It is used in many pharmaceutical preparations, such as *mercurial water*, *red precipitate*, *the alkaline martial tincture*, *the yellow unguent*, &c. &c. We shall take notice of these and the other uses to which it is applied in their proper places.

Species V. *The Sulphuric Acid.*

THE sulphuric acid, which has hitherto been called the *vitriolic acid*, is a very caustic saline substance, which, when concentrated, burns and cauterizes the skin, reddens syrup of violets without destroying its colour, and when diluted in a large proportion of water, has a sour, stiptic taste. This acid, when pure, appears under the form of a very transparent oleaginous

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nous fluid, twice the specific weight of distilled water, destitute of smell, and united with water, from which there are as yet no means known of separating it. It has received the name of the *vitriolic acid*, because it was formerly to be obtained from martial vitriol by distillation. At present it is obtained both in France and England by the complete combustion of sulphur, as we shall explain more at large when we come to give the history of that combustible substance. Its nature, therefore, and the manner in which it is obtained, render it most proper to give it in a methodical and regular nomenclature, the name of the *sulphuric acid*.

When highly concentrated, it is from its consistency named very improperly *oil of vitriol*.

This acid is susceptible of a concrete form; which it may be made to assume either by exposing it to cold, as we shall afterwards see, or by combining it with various elastic fluids.

We know not yet, in what manner light acts on the sulphuric acid. Some chemists have asserted, that when oil of vitriol is exposed in close vessels to the rays of the sun, it gradually assumes a colour, and there is even some sulphur formed. But this fact is not altogether established by proofs; nay, there is even a strong probability against it; for we shall hereafter see, that the sulphuric acid cannot become sulphur without losing its pure air or oxigene;—and it is evident that such a separation cannot take place in close vessels.

Stahl thought the sulphuric acid to be diffused thro' all nature, and to be the principle of all other acids. The first of these assertions was founded on this fact, that linen impregnated with potash, and exposed to the air, is at length converted into sulphate of potash; that

that is, into a neutral salt formed by the union of this alkali with the sulphuric acid. This assertion is at present known to be false; for such linen contains not an atom of sulphate of potash, but a good deal of carbonate of potash, or the combination of this alkali with the carbonic acid. With respect to the second, nothing can be more improbable. Late experiments have shown that each of the acids is formed of peculiar principles; and that there is no principle common to one with another of them, but the base of vital air, which is common to them all.

The sulphuric acid, when heated in a retort, soon loses part of its water, is in some degree concentrated, and is not volatilized unless exposed to a strong heat. If coloured, it loses its colour by the action of fire, and becomes white. This *double* change which it undergoes at *one* time, is called the *concentration* and *rectification* of the acid. While it is taking place, a very odorous and penetrating gas is disengaged, which was the colouring principle of the acid, and with which we shall afterwards get acquainted under the name of the *sulphureous acid gas*. Although this process appears to render the sulphuric acid whiter and more pure, yet it must be carried farther when we wish to obtain the acid in its highest purity: in fact, in this ordinary concentration, we only free the acid of the water and the sulphureous acid gas united with it, without separating any of the fixed matters, by which it may likewise be altered: To effect this, we must distil the acid to dryness, by changing the receiver, after performing the first part of the operation: there remains then in the retort a small quantity of a white residue, which is found to contain sulfate of pot-ash, and some other sub-

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substances which are dissolved in the acid as it is formed.

The concentrated sulphuric acid attracts moisture when exposed to the air, and loses part of its strength and causticity: it at the same time assumes colour, deriving it from the combustible matters which float in the atmosphere, on which this acid acts with no small force. It often absorbs nearly twice its own weight of water from the atmosphere.

The Duke d'Ayen, by a series of curious experiments, performed during the violent cold in the month of January 1776, has shown, that this acid, when highly concentrated, may be made to freeze by exposing it to the cold temperature of from thirteen to fifteen degrees of Reamur's thermometer; but when diluted in two or four parts of water, is no longer liable to the same change of state by cold: and that if when frozen it be left exposed to the air, it soon becomes fluid, even though the cold be more intense than that which caused it to freeze. This last phænomenon is owing to its absorbing water from the atmosphere, and the heat produced while the two are entering into combination.

The sulphuric acid unites with water, displaying, as it enters into union with it, all the phænomena of a sudden penetration and an intimate combination. It produces at the same time a lively heat and a sort of hissing; a peculiar foetid odour is likewise disengaged. The hissing noise excited on this occasion is owing to the disengagement of the air contained in the water, which is seen to make its way out in the form of little bubbles. The taste of the acid, when thus diluted in water, is much weaker than in its concentrated state, its fluidity is much more considerable, and it now bears the name of *spirit*
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of vitriol. The water may be volatilized by heating it; and it may be thus restored by concentration to the state of concentrated sulphuric acid.

This acid acts not in any manner on siliceous earth or quartzose stones, nor on the same earth when melted with the admixture of small pieces of the fixed alkalis. It combines with aluminous earth, barytes, magnesia, lime, and alkalis. In these combinations it forms aluminous sulphate, or *alum*; barytic sulphate, or *ponderous spar*; sulphate of magnesia, or *epsom salt*; sulphate of lime, or *selenite*; sulphate of potash, or *vitriolated tartar*; sulphate of soda, or *Glauber salt*; and ammoniacal sulphate. Its elective attractions for these salts are the same with those of the muriatic and the nitric acids; but it adheres more firmly to these substances than any of the other mineral acids; and is capable of disengaging them.

The action of the sulphuric on the other acids has not as yet been properly examined; we know only, 1. That it absorbs great quantities of the carbonic acid. 2. That it unites so readily with the muriatic acid, that when we mix the two together heat is excited, and a great quantity of muriatic acid gas is disengaged in white vapours. Boerhaave, in his Chemistry says, that the muriatic acid renders *oil of vitriol* concrete: perhaps this property may be found to belong to the oxygenated muriatic acid. 3. That if the pure white nitric acid be poured on a quantity of sulphuric acid blackened by some combustible body, it deprives it of its colour, and renders it transparent; and when this mixture is heated, it exhales a quantity of the nitrous gas. 4. That nitrous gas when united with this acid, has the power of making it assume a concrete form; as shall be shown more

particularly in the article of the decomposition of nitrate of potash by means of sulphate of iron.

The manner in which the sulphuric acid acts on combustible bodies, leads us to an idea of its nature and component principles. Whenever any combustible body, such as a metal, or still more a vegetable or an animal matter, is brought into contact with the concentrated sulphuric acid, that body passes sooner or later into the state of a burnt matter, and the acid is decomposed.

All matters containing oil become black, if immersed in sulphuric acid concentrated and cold. The acid first assumes a brown colour, which soon passes into a black. If an inflammable substance in combustion, such as a burning coal, be immersed into a quantity of sulphuric acid, the acid immediately assumes the smell and volatility of burning sulphur; a white smoke arises from it of a lively suffocating smell. If, in order to comprehend better what passes when these combinations take place, we bring this acid into contact with some combustible body of a more simple character than organic substances, whose alterations may be more easily traced and estimated, we may then attain a knowledge of the principles of the sulphuric acid. If we heat for this purpose a mixture of this acid concentrated with mercury in a glass retort, the extremity of which enters a bell-glass filled with this metallic fluid, as soon as the acid is brought to boil, it emits a permanent gas of a strong pungent smell, resembling that of burning sulphur.

This aeriform fluid is known by the name of the *sulphureous acid gas*: it is somewhat more ponderous than air; it extinguishes lights, kills animals, reddens and discolours syrup of violets. According to Dr Priestley,

ley, it enters into combination with water with less rapidity than the muriatic acid gas; it dissolves chalk, camphor, and iron; coals, and all bodies that are porous in any considerable degree, absorb it. Though it has been considered as a permanent gas, yet by the application of an intense cold, it may be condensed so as to become liquid. M. Monge accomplished this.

The sulphureous is a certain modification of the sulphuric acid, which combines with the alkalis to form neutral salts different from those which they form with the latter. Stahl, who had observed all of these important phenomena with great attention, thought, that in this instance the phlogiston of the metal, uniting with the acid, communicated to it odour, volatility, &c. But as that great chemist did not carry his experiments far enough, he could not foresee, that a strong objection against this doctrine might be drawn from the very fact on which it was founded. M. Lavoisier, M. Bucquet, and myself, have each of us examined the consequences of this reciprocal action of mercury and the sulphuric acid. When the mixture is white and dry, but a very small quantity of the sulphureous acid gas is formed, if this mercurial sulphate be then strongly heated, a little water, and a gas quite different in nature from the former, are disengaged; the gas is very pure vital air. While this gas escapes from the mixture, the mercury is gradually *reduced*, and regains all its original properties, not so much as an eighth part of its quantity being lost. From this it appears, that as the mercury has suffered no alteration, the two gases must belong both to the sulphuric acid which has been decomposed. The sulphureous acid gas appears therefore to bear the same relation to this acid

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which the nitrous bears to the nitric acid. Yet the composition of these two acids is not made up quite in the same manner; for we cannot instantly re-unite the two gaseous principles of the sulphuric acid into the compound body from which they were obtained; whereas we can form the nitrous acid at pleasure, by combining the nitrous gas, and the vital air which it affords when analyzed. It is very likely that a considerable space of time is necessary for the recomposition of the sulphuric acid; for this phænomenon actually takes place when we expose to the air compounds of the sulphuric acid with different bases, these being at length found to contain sulphuric acid. Thus the combination of the sulphureous acid with potash, known under the name of *Stahl's sulphureous salt*, or sulphite of potash, if exposed to the air, becomes at the end of a certain time genuine sulphate of potash. What, in these instances, is slowly effected, takes place with more rapidity in the combustion of sulphur; during which that combustible body absorbs the oxigene of the atmosphere, and becomes gradually more and more acid, till it be completely saturated. (See the *History of Sulphur*.)

From these facts it appears, 1. That the sulphuric acid a compound of sulphur and oxigene. 2. That when a combustible body having a greater affinity than sulphur with oxigene or the base of vital air, is mixed with it, that body decomposes the acid, by absorbing the oxigene. 3. That when the combustible matter does not carry off all of the acidifying principle, as happens in most of the solutions of metals effected by the sulphuric acid, what is separated is not pure sulphur, but sulphureous acid gas. 4. That this gas is a kind of intermediate body between sulphur and the sulphuric acid;

acid; and is to be considered as differing from the acid only by containing a smaller proportion of oxigene; from sulphur, only by containing so much oxigene as renders it faintly acid. To cause it to pass into the state of real sulphur, all that we need to do is, to drive off that portion of the base of vital air which it contains; as happens towards the end of the process in which metals are dissolved by the sulphuric acid when those solutions are strongly heated and made to evaporate. We now likewise understand how the sulphureous is gradually converted into the sulphuric acid, by absorbing the oxigene of vital air contained in the atmosphere.

The sulphureous acid gas is capable of uniting in a very intimate manner with the sulphuric acid, and it then communicates to this acid the property of exhaling in thick white vapours. Meyer, in his Chemical Essays, on the article of Quick-lime, mentions a *fuming oil of vitriol*, prepared at Northausen in Saxony, from a distillation of *common vitriol*. He likewise follows Christian Bernhard, a German chemist, in mentioning a concrete fuming acid salt obtained from this acid by distillation. Finding an opportunity of procuring in Paris a considerable quantity of this sulphuric acid of Saxony, I observed it to possess the properties ascribed to it by Meyer, and obtained from it, by using a gentle heat, crystallized, concrete, volatile salt, fuming and deliquescent, under two different forms, according to Christian Bernhard's account of it. I am convinced, from various experiments related in a Memoir of mine, read in the Royal Academy of Sciences in the year 1785, 1. That the property possessed by this black sulphuric acid of Northausen, of fuming and affording a concrete volatile salt, depends on its containing a great quantity of sulphureous gas. 2. That in proportion as it loses this gas by being exposed to the

the air, it ceases to exhale vapours, and loses its power of affording concrete salt. 3. That water disengages this gas and deprives the sulphuric acid of Saxony of its property of fuming, &c. 4. Lastly, That the fuming concrete acid salt obtained from this acid by distillation is a saturated combination of sulphuric acid with sulphureous gas, which when exposed to the air, gradually passes into the state of common sulphuric acid. We are therefore acquainted with two concrete sulphuric acids, one of which owes its concretion to the nitrous gas, the other to the sulphureous acid gas. I make no doubt but the number of concrete acids may be one day increased, by some other modifications of the sulphuric acid reduced to solidity by other gases; such as the oxygenated muriatic gas, &c.

The sulphuric acid is made use of in many of the arts, more especially by the dyer and the hat-maker, &c. It is one of the most common and useful menstruums in the laboratory. In medicine, it is externally applied as a very useful caustic, and internally as a refreshing, cooling, and antiseptic medicine; but in this case, it must be diluted in water till it have scarce any sensible acidity.

The sulphureous acid is used in dyeing, for whitening silks, taking out stains, &c.

As these two acids are combinations of sulphur and oxigene in different proportions, their names ought to be analogous to their nature: to us they appear to be best distinguished by the names of the *sulphuric acid*, and the *sulphureous acid*. The termination of the word *sulphureous*, serves in this, as well as in other instances, to show that the acid to which it belongs contains an excess of the combustible base.

Species VI. *The Boracic Acid.*

EXPERIMENTS made by a great many chemists have shown borax to be a neutral salt formed by the combination of soda with a peculiar acid; this acid was called by Homberg, its discoverer, *sedative salt*. It has been since named the *acid of borax*, and the *boracic acid*; we choose rather to call it the *boracic acid*, in order that its name may terminate in the same way with the names of the other acids.

Many chemists thought this acid to be merely a product of art formed by the combination of the salts used in obtaining it with some principle of borax: But since M. Hoefer, apothecary to the Grand Duke of Tuscany, has discovered that the waters of several lakes in that country, for instance, those of Castelpuovo and Monterotondo, maintain in solution a considerable quantity of very pure boracic acid; we can no longer entertain a doubt of its being a peculiar acid. The chemists of the academy of Dijon have confirmed this discovery; on examining a quantity of water from the lake Monterotondo sent them out of Tuscany, they found it to contain the salt which M. Hoefer had ascribed to it. It is very likely that the same salt may be found in other mineral waters: it appears, as we shall hereafter mention, to be formed by the putrefaction of fossil bodies.

The boracic acid, whether native or obtained from borax, by processes which we shall have occasion to describe under the article of that neutral salt, is a concrete matter, crystallized in small white scales, very thin, irregularly formed, figured round their edges, extremely light, and sometimes glittering. It has

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weak, yet a sensibly acid taste. It communicates a faint red to tincture of violets; but has a much stronger effect on that of turnsol, mallows, radishes, &c.

When exposed to heat, it is not volatilized; but it melts when made red-hot into a transparent glass; and the glass becomes opaque, and is covered with a light white dust when exposed to the air. This glass is the boracic acid unaltered; it regains its lamellated form when dissolved in water and caused to crystallize.

The boracic acid suffers no sensible alteration from the action of the air, whether it be dry, or moist, or hot or cold.

It dissolves in water, not without difficulty; for, according to the academicians of Dijon, a pound of boiling water dissolves no more than 183 grains of this acid; when cooled and partly evaporated, it returns to its crystalline form. This solution instantaneously reddens the tincture of turnsol, and alters, though more slowly indeed, the colour of syrup of violets. When a quantity of the boracic acid, moistened with a little water, is heated in a cucurbite, fitted with a capital, part of the acid is sublimated together with the vapour arising from the water; but as soon as the whole of the water is volatilized and the boracic acid left dry, the sublimation ceases: from which it appears that the acid is of itself fixed, as may be shown by melting it in a crucible. By sublimating it in this manner with water, if the process be skilfully conducted, it is obtained under a beautiful sparkling crystalline form. The boracic acid, after passing through this process, is very pure, and is known in pharmacy by the name of *sublimated sedative salt*.

The boracic acid serves as a flux to siliceous earth;

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and the glass which they form together is white or faintly coloured. With the help of heat, it dissolves the earth precipitated from the liquor of flints. It unites with barytes, magnesia, lime, and alkalis; and forms by its union with these substances a class of peculiar salts, distinguished by the general name of *borates*, of which we are well acquainted with none but one species.

The whole of these properties, but more especially its taste, and the red colour which it communicates to blue vegetable tinctures, sufficiently distinguish it as an acid. But it saturates alkaline bases only in part; and is known to be the weakest of all acids, as all of the others, not even the carbonic acid excepted, disengage it from the substances with which it combines.

The action of the other acids on the boracic is not well known. It appears to effect a partial decomposition of the sulphuric acid; for when distilled on this salt, the sulphuric passes into the state of the sulphurous acid. As to the nitric and the muriatic acids, we know that they dissolve it; but the phenomena which take place on that occasion have not yet been sufficiently attended to, to enable us to determine whether or not a mutual decomposition then takes place.

A diversity of opinions prevails concerning the nature and the formation of the boracic acid. A number of chemists have believed it to be an intimate combination of the sulphuric acid, and a vitrifiable earth with a fat matter. Messrs Bourdelin and Cadet think it to be formed by the muriatic acid. The latter of these two gentlemen thinks that it must contain a small quantity of earth of copper, because it has the same

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property with the oxides of copper, of communicating a green colour to the flame of combustible bodies. Cartheuser assures us, that on drying and calcining it by the action of a flow fire, a quantity of the boracic acid in a state of great purity, he observed it to emit vapours of the muriatic acid; and that on dissolving this salt thus dried, and filtrating the solution, he found a grey earth remaining after the filtration; and lastly, that by many repetitions of this calcination and solution, he at length accomplished the entire decomposition of the boracic acid, and found it to be a modification of the muriatic rendered fixed by an earth. This experiment has been repeated by Messrs Macquer and Poulletier de la Salle; they observed an odorous vapour to be disengaged during the calcination of this salt, but they were not able to distinguish from its smell that it was muriatic acid. By repeated deficcations and solutions, they obtained a small portion of grey earth; but this earth, when united with the muriatic acid, did not form sedative salt, as Cartheuser had given out; and of consequence this chemist's opinion appears to be no better supported than the rest. Model thought this salt to be a combination of a peculiar alkali with the sulphuric acid, which is used in disengaging it. But this opinion cannot be admitted; for the boracic acid is always the same, whatever be the acid used to precipitate it. M. Baumé says, that he found means to produce the boracic acid by leaving a mixture of grease and clay to macerate for 18 months. At the end of that time, he obtained from it, by lixiviation, a salt in small scales, with all the properties of *sedative salt*. From this he concludes the boracic acid to be a combination of the acid of grease with a very fine earth,

which it is impossible to separate entirely from it. He adds, that the same salt may be produced with vegetable oils, but more slowly. M. Wieglieb repeated M. Baumé's experiment, but without obtaining boracic acid.

Chemists at present think this to be a peculiar acid differing from all others, and possessing certain characteristics of its own. Its elective attractions with alkaline bases are arranged by Bergman in the following order; lime, barytes, magnesia, potash, soda, ammoniac. As they differ greatly from those of the other acids above-examined, they afford an additional proof of the peculiarity of the nature of this acid, whose component principles remain still unknown.

The use of the boracic acid in medicine was first introduced by Homberg, who ascribed to it quieting narcotic qualities, and gave it the name of *sedative salt*, or *volatile narcotic salt of vitriol*, because he had obtained it by sublimating a mixture of *nitre* and *vitriol*. But experience has since shown the medical virtues of this salt to be but very moderate; at least it must be given in a much stronger dose than Homberg has directed, in order to produce the effects he ascribes to it; and it is very properly rejected, as we have many other medicines of the same class, whose effects are much more certain.

It is used in many operations of chemistry, and in the assaying of metals as a flux. We will speak of its application to this purpose in a subsequent chapter.

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ORDER II. SECONDARY, or NEUTRAL SALTS*.

UNDER the name of *secondary salts*, are comprehended all such substances as are formed by the combination of two primary saline matters. They have received the name of *neutral salts*, because they possess not the characteristics of primary salts; that is, they are neither acid nor alkaline. Yet several of them, such as borax, chalk, and alkalis when united with the carbonic acid, exhibit, though in an inferior degree, some of the properties of primary salts. These secondary salts have not so strong a taste as most of the primary;

The author has here the following note.

* The reader may here recollect that this work is divided into four parts. The first, contained in the first volume, explains in eight chapters the general principles of chemistry: The second treats of the mineral kingdom, or mineralogy: The third contains the chemical history of vegetables: The fourth of animal substances.

Mineralogy was divided into three sections. The first, included in the first volume, explains in four chapters the physical and chemical characteristics of earths and stones. The second is appropriated to saline substances. This volume begins with the fifth chapter of the second section.

primary ; nor do they dissolve, or enter into new combinations so readily. But, what principally distinguishes them from the primary is, their inability to communicate saline properties to other bodies. Their crystalline form is another characteristic by which they are distinguished ; it merits the attention of the naturalist ; but, though it sometimes determines their nature, it also occasions frequent mistakes.

The term *base*, is commonly used to denote the more fixed part of the composition of neutral salts. As this base, which is sometimes volatile, communicates several pretty uniform general characteristics to the various combinations with acids of which it admits, we shall use the name of the *base*, to distinguish the genera of secondary salts. These salts may then be divided into so many genera as there are saline or alkaline bases capable of being united with acids.

The first genus comprehends all such as are formed by the union of the two fixed alkalis with any of the acids. These we shall denominate *perfect neutral salts* ; because the union of their component parts is very intimate.

The second genus includes those salts which are formed by the combination of volatile alkali, or ammoniac, with acids. They have received the name of *ammoniacal salts* from the modern name of their base. They may be also called *imperfect salts*, because they are much easier decomposed than those of the former genus.

In the third genus are ranked such as have lime for their base. These are in general more imperfect than those of the second genus, although lime has a stronger affinity than ammoniac with the acids, as shall be after-

wards

wards particularly shown. They are denominated *calcareous neutral salts*.

The fourth genus consists of combinations of magnesia with various acids. These salts are still more easily decomposed than those of the last-mentioned genus; because acids have a stronger affinity with lime and alkalis than with magnesia. Their proper name is *magnesian neutral salts*, or *neutral salts with a base of magnesia*.

To the fifth genus belong those of which the base is pure argillaceous or aluminous earth. Alum being the chief of these combinations, they have received the generic name of *aluminous salts*. Aluminous neutral salts are almost always decomposed by the operation of alkalis, lime, and magnesia.

Lastly, To the sixth genus we assign neutral salts, having a base of barytes or ponderous earth. Both these and the greater part of the two preceding genera are but very little known. *Barytic salts* is the distinctive name of this genus.

It may be easily imagined, that these several bases, when combined with the acids whose properties we have examined, must afford a very considerable number of neutral salts: and this number will be much more considerable, if, with Bergman, we admit as distinct salts the various combinations of these same bases with those acids which he calls *phlogisticated*; and which, according to the modern doctrine, are deprived of a part of their pure air or oxygenous principle. But as these compounds are liable to alteration on coming into contact with air, which causes them almost instantly to assume the character of real neutral salts, it seems improper to add them to a list which is already but too numerous; we shall, however, point out what
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peculiar properties they acquire from the state of their acids. We must observe farther, that though the alkaline bases here enumerated, when combined with aqua regia, afford a mixture of nitrous and marine salts, yet as these may be obtained separate, and are perfectly the same with those produced by the simple acids; we mean, therefore, only to take notice of them when speaking of the combination of alkaline bases with the simple acids. Having hitherto examined no more than six principal acids, we are to treat only of the neutral saline combinations into which these enter.

In the arrangement of the several species of the neutral salts, the most natural order seems to be that of the affinities of the acids: and, therefore, through all the genera, we begin with sulphatic salts, proceeding from them to the nitric; after which we treat successively of those whose bases are combined with the marine, the boracic, the fluoric, and the carbonic acids, the last of which is the weakest of all.

That our nomenclature may be clearly expressive of the nature of the substances to which it refers, the name which we affix to each of these salts is compounded of the name of its acid and that of its base; and the various names by which any neutral salt has been known at different periods are carefully subjoined.

Genus I. *Perfect Neutral Salts*, or *Salts with a base of fixed Alkali*.

Species I. *Sulphate of Potash*.

SULPHATE of potash, which has been also called *vitriolated tartar*, *Sal de duobus*, *Polychrest salt*, and *Arcanum duplicatum*, is a perfect neutral salt, resulting, as its new name denotes, from the combination of the sulphuric acid with potash. It seldom appears in the mineral kingdom; but a few vegetables contain a small quantity of it.

This salt is generally in a greater or a less degree transparent and regular; its crystals differ in form and magnitude, according to the circumstances in which they are obtained. When formed slowly in the small way, they assume the figure of transparent six-sided pyramids, nearly similar to rose-diamonds; and sometimes, tho' less frequently, they take the form of six-sided prisms, terminating in two hexahedral pyramids, much like rock crystal. But if the evaporation be very rapid, the crystals are agglutinated into one mass, under the form of a solid crust, the surface of which is covered with small irregular pyramidal spikes: of this kind is the salt of this name met with in commerce. Lastly, when, in order to obtain the crystals as regular as possible, a solution of this salt is exposed to a gentle spontaneous evaporation by the heat of the atmosphere, its crystals are generally solid twelve-sided figures, joining at the base, and sometimes separated by a short six-sided prism. These indeed are usually foul, and at no time equal the whiteness and transparency of those which are obtained

obtained by the former process of evaporation. But one imperfection attending most of these neutral salts is, that they are either of a dark colour or an irregular figure.

Sulphate of potash has a very disagreeable bitter taste. Fire produces but little alteration upon it. When laid on burning coals, it breaks with noise into a number of little pieces: This phenomenon, which is called *decrepitation*, arises from the sudden rarefaction of the water which entered into it when it was crystallized. But sulphate of potash loses none of its essential properties by decrepitation. It decrepitates in the same manner when exposed to the action of fire in a crucible, and becomes dry, friable, and even pulverulent, by losing the water which it contained: it becomes red before melting, and a strong fire is requisite to bring it to fusion. If exposed to cold when in a state of fusion, it becomes an opaque mass, friable, and soluble: it appears likewise to have suffered no alteration of its principles; for it regains its transparent and crystalline form on being dissolved in water. If kept for a while in the state of fusion in an open vessel, it is volatilized, but without being decomposed.

Sulphate of potash suffers no alteration from air. It remains in its crystalline state, without suffering any change either of form or of transparency. It is scarce soluble in water; yet the difficulty of dissolving it is greater or less according to the temperature of the fluid. According to Spielman, about 18 parts of cold water are required to dissolve 1 of this salt. But boiling water dissolves it nearly in the proportion of 4 to 1; for M. Baumé assures us, that 4 ounces of boiling water dissolve 7 drams and 48 grains of sulphate of potash. It is crystallized partly by cooling, but still

more

more by evaporation : It contains but very little water in its crystals, and therefore suffers no change of state when exposed to the air.

Sulphate of potash acts not at all on simple earths. When accidentally mixed with salts used as fluxes in making glass, it is found again in the scoriæ ; and it is obtained in considerable quantities from glass gall.

According to Bergman, barytes or ponderous earth having more affinity than potash with the sulphuric acid, decomposes this neutral salt. If a solution of this earth be poured on a solution of sulphate of potash, this process forms a precipitate of barytic sulphate or *ponderous spar*, which is absolutely insoluble ; its properties we shall hereafter examine. The potash, if pure and caustic, remains dissolved in the liquor.

Lime and magnesia act not on sulphate of potash ; but many of the acids act very forcibly upon it. Rouelle discovered that it is possible to combine with this salt a greater quantity of the sulphuric acid than it naturally contains. His process consisted in distilling a quantity of concentrated sulphuric acid on sulphate of potash. The neutral salt becomes impregnated with the acid, and acquires new properties : it now reddens the tincture of violets, is soluble in water, has a sour taste, and effervesces with alkalis saturated with carbonic acid, even after being dissolved and crystallized. M. Baumé has maintained, that no real combination takes place between the acid and the neutral salt, and that they may be separated merely by placing them on bibulous paper or sand. But Macquer remarks, that the sulphuric acid adheres with no inconsiderable force to sulphate of potash ; and thinks that their mutual adhesion must be owing to a peculiar affinity between the two substances :

stances : according to him neither fire nor water is able to separate them. I have several times combined the concentrated sulphuric acid with sulphate of potash, in Rouelle's way ; that is, by distilling them in glass retorts, and have observed some phænomena not mentioned in his dissertation on the subject. Sulphate of potash melts on the occasion into a kind of glass or opaque white enamel of a strong acid taste : but this vitreous frit does not attract moisture from the air ; on the contrary, it rather exhibits appearances of efflorescence, when the acid makes only a fourth part of the total weight. There is, therefore, as Macquer thought, a pretty strong adhesion between the neutral salt and the acid ; and that adhesion is no doubt owing to a peculiar combination.

M. Baumé has observed, that sulphate of potash suffers a very considerable alteration from the nitrous acid. If aquafortis be boiled on this salt, the nitrous acid seizes on part of the potash, and disengages the sulphuric acid contained in it. When this mixture is suffered to cool, its crystals are pure nitre. It was at first thought that this decomposition could not take place without the help of heat ; but if fuming spirit of nitre be poured on sulphate of potash in powder, it will be found at the end of some hours to have deposited crystals of nitre. It was likewise advanced, that when the mixture became cold, the sulphuric acid, resuming its rights, decomposed in its turn the nitre of potash : but I have kept mixtures of sulphate of potash with spirit of nitre for several years, and at the bottom of the mixture there were always saline crystals which detonized on burning coals, and suffered no change of nature though immersed in the sulphuric acid separated by the nitrous. M. Cornette has ob-

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served, that the concentrated muriatic acid likewise decomposes sulphate of potash, even cold. From these two facts it would appear, that the law of affinity respecting the different acids does not hold so invariably as was imagined. Yet we must observe, with Bergman, 1. That whatever quantity of the nitrous and muriatic acids be made use of in these experiments, no more than a third part of the given quantity of sulphate of potash is ever decomposed; while the sulphuric acid, when applied in a moderate proportion to nitrous and muriatic salts, effects a total decomposition of them: 2. That such a decomposition never takes place, except when the sulphate of potash contains rather more of the sulphuric acid than is necessary to constitute it a neutral salt.

But of all the modes of decomposition to which sulphate of potash is liable, the most worthy of our attention is that which it suffers from many combustible matters, more especially from charcoal and several metallic substances (See my *Memoires de Chimie*, p. 225.). If a mixture of this salt with coal be strongly heated in a crucible, the sulphate of potash will be converted into sulphur united with the fixed alkali. Stahl thought this a very happy experiment for demonstrating the existence of phlogiston; modern chemists explain it by the pneumatic theory. In the history of sulphur, we shall give both theories.

A quintal of sulphate of potash in crystals contains, according to Bergman, about 52 parts of potash, 40 of sulphuric acid, and 8 of water,—which is necessary to make it crystallize.

As this salt is found but seldom in nature, and even then in small quantities, the sulphate of potash made use of in medicine is always a product of art. There are

three ways of preparing it. First, by a direct combination of the sulphuric acid with potash. This instantly produces sulphate of potash, which may be dissolved in water, and crystallized, as we have mentioned above. The second way is, decomposing; by means of the sulphuric acid, neutral salts consisting of potash united with other acids; such as nitrate, muriate, and carbonate of potash, &c.: Sulphate of potash is infallibly obtained by all of these decompositions. The third way of forming this salt is by using potash to decompose earthy and metallic sulphuric salts. The potash precipitates the salino-terreous substances and the metallic oxides, and seizes the sulphuric acid. We will have occasion to take farther notice of the last two of these methods of preparing sulphate of potash, when we come to give an account of the neutral salts used in the preparation.

This salt is not much used except in medicine. It is a pretty efficacious purgative. It is sometimes given by itself in doses of half an ounce or an ounce. But it is most generally given, a dram or two at once, together with some other purgative medicines. It is used as a solvent in chronical distempers, particularly in coagulations of milk. It is then given in doses of a few drams together in certain preparations of liquids; but its solvent power is much inferior to that of many other neutral salts, which are more soluble and less nauseous.

The sulphureous acid, or the sulphuric with an overplus of sulphur, forms, when combined with potash, a salt somewhat different from that which we have been considering. Stahl called it *sulphureous salt*; we give it the name of *sulphite of potash*. This salt crystallizes in polyhedrons of ten sides, or in two tetrahedral

trahedral pyramids cut towards their bases: it is very bitter, easily soluble, and rather deliquescent. Almost all mineral acids, and many vegetable acids, disengage the sulphureous acid from this salt with effervescence, and in a gaseous form. Sulphite of potash, when exposed to the air, gradually absorbs the oxygenous principle, and is converted into sulphate of potash.

Species II. *Sulphate of Soda.*

SULPHATE of soda, which has been hitherto known by the name of *Glauber salt*, from the name of the German chemist who first discovered it, is a perfect neutral salt, formed, as its name indicates, by the union of the sulphuric acid with mineral alkali or soda. This salt possesses many properties in common with sulphate of potash, and some peculiar to itself. It is equally disposed to crystallize as the other; has a bitter taste; is scarce fusible; dissolves in water; is incapable of union with earths; and, like sulphate of potash, is decomposable in part by the nitrous and muriatic acids. Many of its properties, however, are considerably different from those of sulphate of potash; as we shall see by examining them particularly.

Sulphate of soda is commonly a body of a regular form, and more or less white or transparent. Its crystals are prisms with six unequal and striated sides terminating in dihedral summits. They are seldom under a regular form, and the number of the sides varies well as their size, posture, and striæ; as M. Romé de Lille has shown very particularly in his crystallography.

phy. The prisms of this salt vary in size from the form of small needles, very minute, to prisms half an inch in diameter and six or eight in length ; which last are obtained when a great quantity is crystallized at once. Its taste is at first fresh, but soon becomes very disagreeably bitter. It produces no alteration on blue vegetable colours.

When exposed to the action of fire, it is quickly liquefied : but it soon dries and becomes of an opaque white colour ; in which state it is no less difficult to melt than sulphate of potash. In order to form a just notion of what passes when heat acts with this effect on sulphate of soda, we must take notice that saline substances are melted two ways. 1. By means of the water which enters into their crystals, which is called *aqueous fusion*. This takes place only on such salts as are more soluble in warm than in cold water ; which happens because the portion of the fluid which enters into the constitution of their crystals, being then warmed, dissolves the saline matter. This aqueous fusion is therefore nothing more than solution by warm water : and therefore sulphate of soda assumes again a solid form when it is suffered to cool. 2. But if the heat be continued after it is liquefied, it becomes dry and white : it may then be melted by means of a more intense heat ; and this fusion is actually the effect of fire, and is therefore called *igneous fusion*. Sulphate of soda is therefore no less difficult of fusion than sulphate of potash ; and like it is volatilized by the extreme violence of fire, but suffers no alteration of principles from the action of heat.

It is likewise on account of their containing a great quantity of water, that the crystals of sulphate of soda, when exposed to the air, are in a short time reduced

to a very fine white powder. This phænomenon is called *efflorescence*; because in fact the crystals are covered over with a kind of fine flour, in whiteness and form resembling the sublimated matters which are known in chemistry under the improper name of *flowers*. The cause of this salt's falling down in this manner, when exposed for some time to the air, is its losing the water on which the constitution of its crystals depends. It therefore effloresces most readily when the air is very dry, and of consequence eager to absorb moisture. This phænomenon, therefore, bears a great resemblance to the desiccation effected by heat: both depend on the evaporation of the water to which the crystalline form is owing. Yet, as the water which enters into the crystals of sulphate of soda, and of all efflorescent salts in general, is perfectly combined with the saline matter; efflorescence appears to be owing to a kind of elective attraction between air and water. This phænomenon is therefore to be considered as a decomposition of crystals, taking place in consequence of water's having a greater affinity with air than with the saline matter. Such has always been my idea of efflorescence, and I do not see how it can be explained otherwise (See my *Memoires de Chimie*). Sulphate of soda loses almost half its weight when it undergoes this alteration: but its nature is not changed, and we may cause it to resume its crystalline form, by restoring to it the water which it has lost. Though no writer on *Materia Medica* has as yet made the observation, yet to us it seems an object of some importance, to know the exact quantity of water which sulphate of soda loses when it effloresces, in order that the same quantity may be always prescribed for a dose, in whatever of the two states the salt may happen to be. Rather

more than one-third less of this salt should be given when it is in a state of efflorescence than when it is under the form of fine transparent crystals.

Sulphate of soda dissolves very easily in water. No more than four parts of cold water are necessary to dissolve one of this salt. But a smaller quantity of warm water will be sufficient to dissolve the salt, and a still smaller quantity in proportion as the water is made hotter. One part of boiling water dissolves almost as much of this salt as is equal to its own weight. The method in which we make it crystallize is founded on this property. As it is more soluble in warm than in cold water, all that we need to do is, to leave a strong solution of this salt to cool; and it affords crystals which are more or less regular, and of a greater or a smaller size, in proportion as the quantity of the solution is greater or less, and as it is cooled more slowly or more quickly. In the laboratories of apothecaries, where this operation is performed in the great way, striated prisms several inches long are often obtained, which afford specimens of the regularity of the form of this salt.

Sulphate of soda acts no more on siliceous or aluminous earth than sulphate of potash: and as it is so difficult of fusion, it is no more used in making glass than the other. Barytes decomposes it as well as sulphate of potash; but the other salino-terreous substances produce no alteration upon it.

Pure caustic potash, mixed with a solution of sulphate of soda, decomposes it; because it has a stronger affinity than soda with the sulphuric acid. In order to receive full conviction of this, the reader may pour a lixiviate of caustic potash on a warm and strongly saturated solution of sulphate of soda. This solution, which, if

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suffered to cool, would have afforded crystals of the latter, gives sulphate of potash by evaporation; and the mother water contains caustic soda.

The sulphuric acid combines with sulphate of soda, and adheres to it in the same manner as to sulphate of potash.

The nitrous and the muriatic acids decompose it with the same attendant circumstances as when they decompose sulphate of potash.

When sulphate of soda is violently heated with charcoal and some metals, the sulphuric acid assumes the form of sulphur, as we shall have occasion to mention under the history of that combustible body.

All of the properties in which sulphate of soda differs from sulphate of potash, serve as so many proofs that the two fixed alkalis, however similar in their state of purity, are nevertheless extremely different from each other; because they form very dissimilar salts when combined with the same acid. Besides, the proportion in which the principles of this salt are united is very different from that by which sulphate of potash is formed: for, according to Bergman, a quintal of sulphate of soda contains 15 parts of soda, 27 of sulphuric acid, and 58 of water.

This salt is more copious in nature than sulphate of potash. It is obtained in great abundance from seawater, from the water of certain salt springs, and more especially from many mineral waters. Art can likewise procure it by the three methods of which we have given a description in the history of sulphate of potash. It is not more used in the arts than that salt; but much more in medicine. It is given as a solvent, aperient, and purgative, in doses of—from half a dram to an ounce and an half, according to the cases in
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which it is administered. Its effects are even more strong and quick than those of sulphate of potash; because its sapidity is greater, and it dissolves much more readily in the humours of the human body.

We are ignorant of the properties of sulphite of soda, or of that salt which is formed by the combination of the sulphureous acid with alkali of soda.

Species III. *Nitrate of Potash, or Common Nitre.*

NITRATE of potash, common nitre, or saltpetre, is formed by a saturated combination of the nitric acid with potash. This salt has a fresh taste, is a perfect neutral salt, and does not alter the colour of syrup of violets. Its crystals are six-sided prisms, terminating in dihedral pyramids, or cut off with a slope, and often channelled from one end to the other.

There is great abundance of this salt in nature: it is continually forming in places inhabited by animals. It is likewise found in abundance on walls sheltered from rain; and is then called *saltpetre de bouffage*.

There seem to be three circumstances which chiefly promote its formation. The first of these is the presence of chalk, or some calcareous substance: in this manner is the nitre formed which is gathered on walls covered with plaster; and from this circumstance, considerable quantities of nitre are usually found on the demolition of old buildings. This salt is obtained in a state of perfect purity from chalky earths. The Dûke de la Rochefoucault has obtained it in the proportion of an ounce to the pound from chalk of Roche-Guyon.

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The second circumstance favourable to the production of saltpetre is the putrefaction or spontaneous decomposition of animal and vegetable matters. It is a well known fact, that places watered with animal liquors, or containing animal matters in a state of putrefaction, such as dunghills, stables, jakes, afford great quantities of nitrate of potash. This fact has always been gone upon as a principle, in forming beds for the artificial production of nitre. Ditches or covered sheds are formed, and left exposed on all sides to the air: these are then filled with putrescent substances, such as dung of all kinds, and vegetable substances; water containing animal or vegetable matters is from time to time poured on the mass; and it is stirred now and then to change the relative disposition of the surfaces. When the putrefaction is considerably advanced, a small portion of the matter is taken and lixiviated, in order that it may be known whether it contains nitre; and if it be found to contain a sufficient quantity of the salt, the whole mass is subjected to the same process.

The third circumstance apparently favourable to the production of nitre, is the contact of the air. This is one great cause of the formation of the saltpetre found on walls; and it is on this principle that the mixture deposited for the artificial production of nitre is frequently stirred, in order that the air may have access to every part of the mass. Beds of chalk, which naturally contain nitre, afford it only to a certain depth, and not lower. Where these three circumstances meet, nitre is produced in great abundance. Beds for the artificial production of nitre should be formed on these principles.

It

It is but a very short time since the theory of the production of nitre came to be known. Glauber, and a number of chemists who implicitly adopted his opinion, thought this salt to be entirely formed in vegetable substances, in them conveyed into the bodies of animals, and by putrefaction only disengaged into a free separate state: But it was soon observed, that the vegetables used for its production in nitre-works could not be sufficient to afford, of themselves, the quantities obtained. M. Thouvenel, who by his essay on the formation of nitre gained a prize from the Academy, made a great many experiments with a view to discover its cause, and found that the nitric acid was formed by the combination of an elastic fluid disengaged from animal matters in a state of putrefaction with vital air. He has also shown that this acid, when formed, combines with calcareous earth, where nothing but animal matters is used for nitre beds; and that the use of vegetable substances is to furnish fixed alkali or potash, which is the base of common nitre. M. Thouvenel had not determined the nature of the gas which is disengaged from animal matters in a state of putrefaction. And Mr Cavendish has since shown it to be the same with that which, under the name of phlogisticated air, atmospheric mephitic, or azotic gas, constitutes one of the principles of the atmosphere. By combining this gas with vital air, by means of the electric spark, he obtained a product of genuine nitric acid.

Nitrate of potash is very liable to alteration from heat. When exposed to the action of fire in a crucible, it soon liquefies—by igneous fusion; for though kept for some time in that state, it does not become dry; and though made red hot, does not assume a pulverulent form. When suffered to cool, after being melted,

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it congeals into an opaque mass which is named *crystal mineral*, and is equally ponderous, fusible, and soluble with nitrate of potash. The crystal mineral of the apothecaries shops is somewhat different from pure melted nitre : for it contains a little sulfate of potash, produced by the combustion of sulphur, which, according to the Parisian pharmacopœia, is used in the proportion of a dram to the pound of nitre in the preparation of it.

If nitrate of potash be left exposed to the action of fire, after being melted, it will be of itself decomposed and reduced to alkali. This operation succeeds equally well in a retort ; and when performed in this manner, is of use to explain the decomposition of the nitric acid. In fact, instead of the nitric acid passing off pure, there escapes a large quantity of an aeriform fluid, which may be collected under water, and is found to be genuine vital air mixed with azotic gas. The residue of alkali usually melts the retort very soon after it is separated ; and when we wish to pursue the operation to a conclusion, we must use a stone retort which may be proof against its action. Here we have the nitric acid entirely decomposed into vital air and azotic gas by means of heat, which alone is able to separate these two principles. If the heat be not continued so long, or made so intense, as to effect the entire decomposition of the nitrate of potash, the alkali still retains a certain quantity of the nitrous acid, or of the nitric with an excess of nitrous gas. This acid may be disengaged from it by vinegar. In this state, the salt is what we call *nitrite of potash*, the nitrous acid being supersaturated with azotic gas ; in the same manner we called the combination of the sulphureous acid with potash, *sulphite of potash*. If nitrate of potash be acted upon
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by a very intense heat, a residue of pure caustic alkali is obtained. Since heat decomposes nitrate of potash with such facility, it may be naturally inferred, that when crystal mineral is prepared by simple fusion, the salt must not be too long exposed to the fire. If this precaution be neglected, the medicine will contain more than a just proportion of potash, and will produce too violent effects.

The decomposition of nitrate of potash is attended with other phenomena, when it is exposed to the action of fire, together with combustible bodies. When laid on a coal it gives a white lively flame, attended with a kind of decrepitation: this is called the *detonation*, or *fusion of nitre*: the salt is then said to detonize or melt; and by this characteristic nitre may be at any time easily distinguished. Stahl thought this phenomenon to be owing to the rapid combination of the acid of nitre with phlogiston; and M. Baumé proceeding on the same theory, thought that in this operation a quantity of nitrous sulphur was formed, which was instantly inflamed. In the year 1780, I read in the Academy a Memoir, in which I have shown that nitrate of potash is neither combustible of itself nor yet forms nitrous sulphur when it detonizes; and that this phenomenon is entirely owing to the slower or quicker combustion of the combustible matter necessary to make the salt detonize, in consequence of the disengagement of the vital air, which escapes in great abundance from nitrate of potash strongly heated. This theory is completely proved: 1. Because the salt never detonizes by itself. 2. Because after its detonation by means of an inflammable matter, that matter is found to be entirely burnt up. 3. Because the greater the quantity of the nitrate of potash in proportion to

that of the combustible matter, the more complete is the combustion of the latter substance. 4. Because detonation takes place as well in close vessels as in the open air, which could not possibly happen if the salt did not furnish vital air. This assertion receives the fullest support from the phænomena attending the process for making the clyffus of nitre; which is merely a detonation of this salt with different combustible matters in close vessels. We shall mention here only that which is made with charcoal. Two or three large receivers fitted together are applied to a retort of earth or iron, with an orifice in the upper part, which may be closed with a cover or stopper. This vessel is heated till its bottom be made red, and then a mixture of nitrate of potash with coal is put in by the orifice, which is immediately shut. During the detonation, the receivers are filled with vapours, part of which is condensed into an insipid liquor, not at all acid, but often alkaline. The residue is potash saturated with carbonic acid: the nitric acid is then totally decomposed, and a large quantity of gas is produced, which I have collected by fitting to the orifice in the upper part of the receivers, either a bladder or tubes, the extremities of which entered glasses full of water. This gas was mostly carbonic acid mixed with a little inflammable and azotic gas; the last of which is one of the principles of the nitric acid. The inflammable gas is produced in consequence of the decomposition of part of the water of nitre by the charcoal.

The residue, after the detonation of nitrate of potash with charcoal in a crucible, is improperly called *nitre fixed by charcoal*: it is potash combined with carbonic acid.

Nitrate

Nitrate of potash, when very pure, suffers no alteration from the action of the air.

It is easily soluble; for three or four parts of boiling water dissolve one of nitre, and boiling water dissolves a quantity of it equal to twice its own weight. It therefore crystallizes very readily by cooling. On its possessing these two properties is founded the art of extracting nitrate of potash from plaster or rubbish containing it. The saltpetre makers put the pounded plaster or rubbish into a vessel with a hole at the bottom, and cover it with ashes. Through this matter they pour water; taking care to pour pure water on rubbish that has been already washed, till it be deprived of all the nitrous matter it contains; and pouring water already impregnated with nitre upon the unwashed rubbish, in order that it may be completely saturated. They next evaporate the lixivium thus formed in copper vessels. They skim off the first pellicles, which are only the muriate of soda or marine salt contained in the rubbish. This salt they call *grain*; and by their regulations, they are obliged to carry it to the refining houses. When the water is evaporated to such a degree, that the residue when cool must become solid, they put it into other vessels in which the nitrate of potash is crystallized. This salt, which is very impure and dirty, is called *nitre of the first boiling*. Some chemists have been of opinion that the ashes used in making saltpetre served only to cleanse the nitrate of potash of certain greasy impurities; and that opinion appeared to be supported by the fact, that these matters contain almost no alkali, and the ashes of tarmarisk, used by the salt-petre makers of Languedoc, contain only sulphate of Soda. But this salt, as well as sulphate of potash, is as useful as an alkali for decomposing the calcareous nitrate, which is found in such abundance

dance in plaster or rubbish, by the way of double elective attraction, as M. Lavoisier has observed with respect to the lixiviated ashes used by the saltpetre makers of Paris. We shall say more upon this under the article of *Calcareous Nitrate*.

Nitrate of potash of the first boiling is always very impure. It contains five other kinds of salts besides pure nitre; namely, muriate of soda, nitrate of magnesia, calcareous nitrate, muriate of magnesia, and calcareous muriate; and these must be separated, if we wish to obtain nitrate of potash in a state of purity. The mixture is purified of these salts, by dissolving it again in the smallest possible quantity of water, and clarifying this boiling liquor by means of bullock's blood, which carries off all impurities by collecting them on the surface in the form of a scum. This lixivium is then evaporated, and by cooling the residue, a nitrate of potash is obtained, much purer than the former, which is said to be *nitre of the second boiling*. Still, however, it is vitiated by a certain quantity of muriate of soda and mother-water. It is a third time purified by the same process, and it then becomes much purer and whiter; it is now *nitre of the third boiling*. As it is made to crystallize very rapidly, it is obtained in large irregular masses; and yet in the middle of the vessels there is formed a layer of long regular crystals, which is called *nitre in sticks*. Nitre under this last form is not used in arsenals, being not so fit for making good gun-powder as nitre in large irregular masses; because the water which entered into it when it was crystallized would retard the combustion of the powder.

Chemists and apothecaries go on to purify nitre of the third boiling by new solutions and crystallizations.

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By this means they are certain of at length obtaining very pure nitrate of potash, entirely free of every extraneous mixture, and containing no muriate with either soda, or lime, or magnesia for its base. Though these are scarce ever taken entirely away where the operation is performed in the great way *.

Nitrate of potash appears to be liable to some alteration from siliceous earth; for by distilling it with sand the acid is separated. This acid comes off colourless, but some vapours are diffused at the time. The residue is vitreous in a greater or a less degree, according as there was a greater or a less quantity of sand employed, and as the heat was weaker or more intense. Sand appears to decompose nitrate of potash by its tendency to combine with its alkaline base: for when nitre is distilled without any intermediate body being used, there is no nitrous acid, but a mixture of vital air with azotic gas, obtained. The reason of this I take to be, that when nitre of potash is distilled without an intermedium, the alkali reacts on the acid, and contributes to its decomposition; whereas, when this salt is heated with a mixture of sand, the sand, by its tendency to form glass by combining with the potash, prevents the alkali from reacting on the acid, which therefore escapes unaltered.

* There is no more extraordinary natural or chemical fact than the production of six species of salt in the rubbish of old houses, each of the alkaline bases being constantly united with a peculiar acid. Potash is always united with the nitric acid, and soda is always combined with the muriatic. There would seem to be some particular relations between these different kinds of primary salts, in consequence of which they mutually select each other; for why is there no muriate of potash or nitrate of soda? The same thing might be observed of the earthy salts: in fact, there is much more muriate of magnesia and calcareous nitrate, than nitrate of magnesia or calcareous muriate: and this shows magnesia to have a peculiar affinity with the muriatic, and lime with the nitric acid.

ed. Argillaceous earths likewise decompose nitre. Coloured clay is generally made use of for this purpose. The distillers of aquafortis in Paris make use of an earth of this kind. Into earthen retorts, of a peculiar form, called *cuines*, they put into each two pounds of nitre, of the second boiling, with six pounds of coloured clay of Gentilly: the retorts are arranged one beside another, in long furnaces known by the name of *galleries*; and the neck of each retort enters a bottle of the same form, serving as a receiver. By this means they obtain at first a transparent liquor, somewhat acid, which they call *phlegm of aquafortis*, and afterwards the acid gradually more and more concentrated. The residue is a very hard, red, earthy substance, which serves for making a kind of mortar. But this experiment by no means proves that clay decomposes nitre of potash:—For, 1. The nitre used by the distillers is very impure, containing a great deal of earthy nitre: 2. The clay which they make use of is of a very compound nature, often containing a great quantity of pyrites, the vitriolic acid of which may possibly decompose the nitre. In order that this decomposition might determine the fact in question, it should be made with white clay, or rather with the base of alum or aluminous earth. As this earth has not so great a tendency as sand to unite with the alkali, and does not form glass by combining with this salt, it does not seem capable of effecting so complete a decomposition of nitre of potash as sand produces. M. Baumé, however, says, that he obtained the acid of nitre of potash by the addition of porcelain and clay baked in stone-ware; but he thinks the decomposition of the salt was owing to the acid contained in the clays.

Barytes decomposes nitre of potash, and separates the

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alkali.

alkali. Bergman, in his table of affinities, places this salino-terreous substance before the alkalis, and immediately after the nitric acid.

Magnesia, lime, and the alkalis, act not upon nitre. But the acids act in a very distinct manner on this salt, particularly the sulphuric acid, which has really a greater affinity than the nitric acid with the alkalis. When a quantity of concentrated sulphuric acid is poured on a quantity of dry nitre of potash, a considerable effervescence is produced, and red vapours are seen to arise, which are actually nitrous acid. By performing this operation in a receiver with a retort fitted to it, we may collect this acid: it is known by the name of *spirit of nitre*. This operation is called in the laboratories, *the distillation of the spirit of nitre in Glauber's way*; because Glauber was the first who gave a plain intelligible description of it. The receiver used in this operation must be perforated with a small hole, to give vent to the vapours of the nitrous acid. It was remarked, that there was much difficulty in condensing these vapours, and the process was liable to two accidents. The first was, the loss of no small portion of the spirit of nitre which escaped through the orifice of the vessel: the second, the danger to which the operator was exposed from such extremely acrid and corrosive vapours. This process was therefore very defective. Mr Woulfe, an ingenious English chemist, has found means to obviate these inconveniences. Instead of using a receiver perforated with a little hole, he has adopted one with two necks. Into the extremity of this vessel, which is farthest from the receiver, he puts a tube, one end of which being in an horizontal position, makes a right angle with the other, which is vertical and inserted into a bottle. This bottle has

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in its sides two orifices; each of these receives a syphon which passes into another bottle standing beside the first. The two collateral bottles are joined by means of a syphon with two others, of which the lateral apertures remain open. The first bottle generally remains empty: the collateral bottles contain a quantity of water, in which the lower and longest extremity of the tube which communicates between the two is immersed: the upper part of the bottles remains empty; and the acid vapour is conducted by the tubes through the bottles. By the use of this ingenious apparatus, the artist is secured from all danger, and nothing is lost. The nitrous acid in vapour passes through the retort into the first bottles, and is there condensed; and what is not condensed in the first passes into the second bottles, and there unites with the water. From the lateral apertures of the last bottles, there escapes a certain quantity of vital air, which may be received into proper glasses. This apparatus, as here described, possesses one advantage worthy of our notice: When the retort is left to cool at the end of the operation, a vacuum is produced in the vessels, and the external air pressing on the water in the outer bottles standing open, forces it through the syphons into the inner collateral bottles; and from these again it passes into the middle bottle standing nearest to the retort. If the first bottle were not empty, or not large enough to contain all the water from the others, the acid liquors would pass into the receiver: and as the strongest nitrous acid is contained in that vessel, it would be mixed with the liquors from the bottles, and therefore would not possess the required strength. This circumstance would be still more inconvenient in other instances of distillation, of which we are hereafter to

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speak;

speak ; because it would not simply weaken the strength of the product, but would even alter its purity.

In performing this operation in a laboratory, four pounds of pure nitrate of potash, melted into crystal-mineral, are put into a tubulated stone retort, placed in a reverberating furnace ; or tubulated glass retorts may be used in a sand-bath. Two pounds and an half of concentrated sulphuric acid are poured in at once through the aperture, and it is then shut. The apparatus above described, which we suppose to have been prepared and put together on the preceding evening, is to be instantly applied and luted to the retort ; it is next to be gradually heated till nothing more comes over. The disengagement of the gas, and its passage into the bottles, serve to direct the operator in conducting the process. If the gas appear to be disengaged with too much rapidity, the heat is then too violent, and must be diminished, otherwise the whole mass in the retort will swell up and pass into the receiver : But again, if it pass too slowly, the fire must be increased to prevent the absorption of the gas. This apparatus is therefore happily formed to direct the artist in the management of his process.

The residue, after this decomposition, is sulphate of potash, formed by the union of the sulphuric acid with the alkaline base of nitre. This residue is known in pharmacy under the name of *sal de duobus*, or *arcanum duplicatum*. It is usually a white opaque mass, half vitrified, and filled with cavities produced in it when it was swelled by the heat. This salt is strongly acid, on account of the quantity of sulphuric acid made use of in producing it ; and it is the excess of the acid which causes the salt to melt, as we have seen under

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the history of sulphate of potash. The nitrous acid obtained by this process is very red and fuming, because the intense heat employed in the distillation disengages a portion of vital air. As it is always mixed with a certain quantity of sulphuric acid, it is to be rectified by a new process of distillation on a quantity of nitre equal to one-fourth of its own weight. We must likewise observe, that the nitre made use of on this occasion must be very pure, in order to afford nitrous acid in such a state that we may depend upon its effects. That which is obtained from nitre of the second boiling, contains muriatic acid, and acts with the solvent power of aqua regia. This acid may be purified of the muriatic acid which it contains by a distillation judiciously managed; as is shown by Messrs de Laffone and Cornette (*Mem. Acad.* 1781, p. 653 to 656.).

The concrete boracic acid decomposes nitre with the help of heat, disengaging from it the nitric acid in a concentrated state. It appears to effect this decomposition by means of its fixity; which is the opinion of the academicians of Dijon. Yet it must be also ascribed in part to the mutual attraction between the boracic acid and the potash base of nitre.

Nitre of potash is much used in the arts. It is the principal ingredient in gunpowder; of which composition we will have occasion to speak under the article of sulphur. When burnt with various proportions of tartar, it forms the melting matters called *fluxes*, which are used in the assaying of metals for melting and reducing metallic substances, &c. &c.

It is often used in medicine as a quieting, cooling, refreshing, diuretic, antiseptic medicine, &c. It is given in any kind of drink, in doses of—from ten or

twelve grains to half a dram and more. Physicians have daily instances of its good effects.

Species IV. *Nitrate of Soda.*

NITRATE of soda, which has been called *cubic*, *quadrangular*, and *rhomboidal nitre*, is a perfect neutral salt, resulting from a saturated combination of the nitric acid with soda.

This salt generally appears in pretty large and very regular rhomboidal crystals. The name of *rhomboidal nitre* describes it better than that of *cubic nitre*.

Its taste is fresh, and rather more bitter than that of nitre of potash.

Fire decomposes this as well as the preceding salt; but it decrepitates, and does not melt so easily as the other. It affords a mixture of vital air with azotic gas, with an alkaline residue like nitre of potash.

It is rather more subject than nitre of potash to alteration from the air, and attracts moisture, though not with much force.

It dissolves in cold water even more readily than the former salt; for two parts of water, at the ordinary temperature of 60° , are sufficient to dissolve one part of nitrate of soda. Boiling water scarce dissolves it in a greater proportion: and therefore, when we wish to obtain it in regular crystals, the solution must be slowly evaporated. If a tolerably clear lixivium of this salt be set aside in a dry place, at the end of some months it is found to contain rhomboidal crystals, six or eight lines, and sometimes near an inch, long. This is usually the happiest process for crystallizing salts that are as soluble in cold as in warm water.

Nitre

Nitre of soda detonizes on burning coals, and inflames any combustible body heated along with it,—rather more slowly than nitre of potash.

Siliceous earth disengages the nitric acid, and unites with its base to form glass. Clay also separates the acid, giving as a residue a kind of grit, which becomes porous and opaque after being exposed to a strong heat.

Barytes decomposes it, and leaves the soda pure. Magnesia and lime produce no sensible alteration upon it.

Potash having more affinity than the base of this salt with the nitric acid, attracts it to itself, and forms with it nitre of potash. We obtain conviction of the truth of this fact by a very simple experiment. If a boiling saturated solution of nitre of soda be divided into two portions, and into one of these there be thrown a quantity of caustic potash, the portion which received this addition will deposit, when it cools, prismatic crystals of nitre of potash; while the other into which there was no potash put, will exhibit no crystals at all, because nitre of soda crystallizes only by a very slow evaporation.

If concentrated sulphuric acid be poured upon nitrate of soda, it will disengage the nitrous acid with effervescence. Nitrous acid is obtained by a distillation of this mixture, as well as from nitre of potash. The other mineral acids act no more on this salt than on the foregoing.

The neutral salts which have been already examined, sulphate of potash and soda, and nitrate of potash, produce no alteration on nitrate of soda. When these salts are all dissolved in the same water, they crystallize separately, each in its ordinary way: Nitrate of

potash and sulphate of soda, by cooling ; sulphate of potash and nitre of soda, by evaporation. From all of these properties it appears, that nitrate of soda differs from nitrate of potash only in its form, its taste, its slight tendency to deliquiate, its being of easier solution, and its crystallizing by evaporation, and chiefly by its susceptibility of decomposition by potash.

Nitrate of soda has not been yet found in nature. It is always a product of art, and is formed in the five following ways : 1. By the direct combination of the nitric acid with soda. 2. By decomposing with this alkali earthy nitrates, ammoniacal nitrate, and metallic nitrates. 3. By decomposing muriate of soda with the nitric acid for an intermedium. 4. By decomposing sulphate of soda by the fuming spirit of nitre. 5. By decomposing such nitrous solutions of metals as are susceptible of it with muriate of soda : In this instance, in proportion as the muriatic acid combines with the metal, separating from it the nitric acid, the separated acid combines with the soda, which has also deserted the acid with which it was before united. All of these decompositions will be particularly described in the respective histories of the salts which are liable to them.

Nitrate of soda might be employed for the same purposes as nitrate of potash. But as it does not produce all the effects of that salt, doubtless on account of its having a greater affinity with water, it is not made use of in the arts. Besides, as it is not found in nature, but is merely a product of art, no attempt has been made to apply it to any particular use. A sufficient number of experiments has not yet been made on this salt to make us acquainted with all its properties.

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Species V. *Muriate of Potash.*

MURIATE of potash, which was formerly called *febrifuge salt of Sylvius*, is a saturated combination of the muriatic acid with potash. It has been improperly named *regenerated marine salt*; for the nature of its base renders it different from that salt. Its crystals are cubic, but always of a confused appearance, and rather an irregular form. Its taste is salt, pungent, bitter, and disagreeable. When exposed to fire, it decrepitates; that is to say, its crystals break into small pieces, which is occasioned by the sudden rarefaction of the water which enters into their composition. If suffered to remain in the fire after decrepitation, it melts and is volatilized, but not decomposed. It may be used as a flux for earths and metallic substances. Its chief use in such cases is to cover the matters to be melted, and by that means fix the action of other fluxes employed, hindering them from becoming volatile, and preventing such alterations as might be occasioned by the access of air.

Muriate of potash is subject to little alteration from the air, as it scarce attracts moisture.

About three parts of cold water are necessary to maintain in solution one of this salt; nor has hot water any greater power of dissolving it. For this reason a slow evaporation is used to give it in crystals. It is one of those salts which it is very difficult to obtain in regular crystals of a certain size.

Clay seems to decompose it in part: for muriatic acid may be obtained by distilling this salt with the clays in the neighbourhood of Paris. That operation
indeed

indeed affords but a small quantity of the acid, and its result is very different from that which nitrate of potash affords. Sand is also known to act in the same manner as clay on muriate of potash.

Barytes, according to Bergman, seizes the acid, leaving the potash in a separate state. Magnesia and lime produce no alteration on this fact.

The sulphuric and the nitric acids disengage the muriatic with effervescence*. This phænomenon is the more striking if the potash be dry. Muriate of potash, after decrepitating, and losing the water of its crystals, gives a very considerable effervescence with the concentrated sulphuric acid, and the mixture becomes very warm. Where these decompositions are performed in retorts, muriatic acid passes into the receiver, and the residue in the retort is found to be sulphate of potash,—if the sulphuric acid was employed to effect the decomposition; but if the nitric acid

was

* We have already observed, when speaking of the decomposition of nitre of potash by the concentrated sulphuric acid, that the nitrous acid is then disengaged with a lively effervescence. We find the muriatic acid exhibiting the same phænomenon; in a much more eminent degree indeed, because this acid has a very strong tendency to assume the gaseous state. This is the general cause of all effervescences, the nature and distinctions of which have, till of late, been but very imperfectly known. It was formerly thought that they were owing to the disengagement of air: we now know them to be produced, not by air, but by all bodies which have any tendency to the state of aeriform aggregation; and thus we have shown, that the ebullition of water may be considered as a sort of effervescence. As this truth needs to be frequently repeated, in order that it may become generally known, we shall take occasion to recur to it several times when treating of the different neutral salts which admit of decomposition by acids.

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was used, aqua regia is obtained in the receiver, and the residue is nitre of potash. The boracic acid likewise decomposes muriate of potash by distillation, disengaging the muriatic acid. As all of these operations are done with muriate of soda or marine salt, we shall give a more particular account of them under that article. Neither the fluoric nor the carbonic acid acts in any way on the muriated potash.

Neither sulphate nor nitrate of potash or soda acts upon this salt. When all are dissolved in the same water, each of them is crystallized separately and in its own way.

Muriate of potash is frequently met with in nature; but never much of it together. It is found in sea water, and in the water of salt springs; sometimes, tho' not often indeed, it is met with in the same places where nitre of potash is found; it is also found in ashes of vegetables, and in some animal humours. Art produces it, 1. By a direct combination of the muriatic acid with potash; 2. By decomposing earthy, ammoniacal, or metallic muriates by the same alkali; 3. By decomposing sulphate or nitrate of potash, by means of the muriatic acid, as M. Cornette has shown.

This neutral salt was formerly administered as an excellent febrifuge. But it possesses not this property otherwise than in common with all bitter salts. Sulphate of potash or soda is now preferred to it.

Muriate of potash is applied to no use in the arts. Its disagreeable taste hinders it from being used, like muriate of soda, for seasoning. But it has all the chemical properties of that salt; and the only difference between them is, that muriate of potash has a bitter taste, is more difficult of solution, is unalterable by the air,

air, and is irregularly crystallized. We shall therefore insist no more upon its history.

Species VI. *Muriate of Soda.*

MURIATE of soda, better known under the name of *culinary* or *common salt*, is a perfect neutral salt, formed by a saturated combination of the muriatic acid with soda. The reader will perceive that the nomenclature which we have hitherto used, renders a definition of the nature of these neutral salts almost unnecessary; as the name of each is expressive of its nature.

This salt abounds in nature more than any other species. It is found in vast masses in the interior parts of the earth, in Spain, Calabria, Hungary, and Muscovy, but more especially at Wieliczka in Poland, near the Crapack mountains. In the last of these places the mines are of vast extent, and the muriate of soda is found in prodigious masses. This salt, as it exists in the earth, is generally irregular, and seldom crystallized; it is usually more or less white, but sometimes coloured: in this state it is called *gem-salt*, having often the transparency of the crystals known under that name. The waters of the sea, as well as of some lakes and rivers, contain this salt. From these waters it is obtained by four general processes.

The first is spontaneous evaporation by the heat of the sun. This method is used in our southern provinces, in Languedoc, at Peyrac, Pécas, &c. Trenches are cut on the sea shore, and very compactly lined with clay: within these trenches little walls are built, dividing them into certain compartments, yet leaving a general communication. When the tide flows, the

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trenches are filled with water, which is retained in them by the walls forming a kind of sluice-gates. Care is taken that the layer of water retained be thin enough to be readily evaporated by the rays of the sun. As soon as a saline pellicle is formed, it is broken, and the fragments fall to the bottom; and the same process is repeated till the water be entirely evaporated. The salt is then gathered with rakes, and laid in heaps to dry. This salt contains a mixture of all the other salts that exist in a state of solution in sea-water, such as sulphate of soda and magnesia, muriate of magnesia and lime: it is also contaminated with a portion of clay from the bottom of the trench: and, lastly, small globules of iron and mercury are found in it. The existence of the latter in it may be easily shown by leaving a small piece of gold among the salt for some time: it becomes evidently whiter. This salt being very impure, is known under the name of *sel de gabelle*.

In the northern provinces of France, in Normandy and Brittany, this salt is prepared by an artificial evaporation by fire. In Avranches they take the quicksands among which the sea water has deposited saline crystals, and wash them in the smallest quantity possible of sea water, in order that no more may be used than what is necessary to dissolve the salt: This salt water is then put into lead vessels, and evaporated to dryness. This salt is very white, and purer than that prepared by evaporation in trenches. Guettard has given a careful description of the whole process in the Memoirs of the Academy for the year 1758.

In Lorraine and Franche-Comté there are a great many salt springs. The quantities of muriate of soda which those springs contain in proportion to the quantity

tity of water are various. At Montmorot, in the last of these provinces, both spontaneous evaporation and evaporation by fire are used in the preparation of this salt. For that purpose, the well-water is conveyed by pumps into a large reservoir placed at the top of a shed of a peculiar construction. Under this shed are suspended boards covered with little faggots of thorns. The water falling upon those faggots through small cocks, is divided into very minute drops: and as it thus exposes a great deal of surface to the air circulating rapidly under the shed, nearly two-thirds of it is evaporated. What is deposited on the faggots is sulphate of lime or selenite. And when the liquor, upon trial with an instrument for the purpose, is found to be charged with salt to a certain degree, it is conveyed into large iron boilers supported by bars of the same metal, which cross the bottom of the vessels, and rest on pieces of wood placed on each side. Those boilers, which are called *stoves*, are very large and shallow, and hold an hundred hogsheads * of the salt water. They are then urged with a strong fire. When the water boils up in large bubbles, it is at first muddy, and soon deposits an ochreous earth on its surface in the form of a scum. A salt, which is scarcely soluble, and is called by the workmen *schlot*, is next separated: This salt is nothing but sulphate of lime mixed with a little muriate of soda, sulphate of soda, and earthy muriates. It is conveyed by the circulation of the boiling liquor into little troughs placed round the sides of the boilers for the purpose. These troughs are taken out and cleared from time to time till a great quantity of

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* *Muids*, containing each 280 French pints.

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small cubical crystals called by the workmen *pieds de mouches*, are observed floating on the surface of the liquor. They are then taken away for the last time. The fire is diminished, and the muriate of soda is taken off with ladles as fast as it is crystallized. The evaporation is thus continued as long as the water continues to afford crystals. The salt thus obtained is in larger or smaller crystals, according to the slowness or rapidity of the evaporation. The water which remains when crystals are no longer obtained, is called *mother water*, and contains earthy muriates*.

Wallerius gives an account of a fourth process for obtaining salt from sea water, which is practised in the north. The water is confined in trenches on the shore: as it forms but a small stratum, the cold soon penetrates through and freezes it. But as that portion necessary for the solution of the salt contained in the whole quantity of water cannot be converted into ice, what remains fluid contains all the salt, and is so concentrated that the most moderate heat causes it to afford muriate of soda in crystals: it is then conveyed into leaden boilers, and evaporated by fire.

The crystals of muriate of soda are very regular cubes, of a larger or a smaller size, in proportion as the evaporation has been slower or more rapid. They stick together in clusters, forming a kind of ladders, or rather hoppers. Rouelle the elder observed this phenomenon, and has given an accurate description of it in his

* There is a neutral salt prepared at Montmorot, known under the name of *Epsom salt of Lorraine*: but it is only sulphate of soda, or Glauber salt, the crystallization of which has been disturbed. It is distinguished from genuine sulphate of magnesia and Epsom salt, such as comes from England by its efflorescing in the air, while the latter deliquesces.

his Memoirs on CrySTALLIZATION. Bergman has given a very ingenious explanation of this fact.

Every body knows the taste of this salt, which is not disagreeable.

When exposed to a brisk heat it bursts and flies into pieces. This phenomenon is called *decrepitation*. It is owing, as we have already observed when speaking of sulphate and muriate of potash, to the sudden rarefaction of the water on which the crySTALLIZATION depends. When all the water is thus evaporated, the decrepitation ceases, and the salt appears in a powder. If we continue to urge it with a strong heat, it melts after becoming red-hot. If poured in this state on the plane surface of a piece of marble, it congeals into a kind of crystal mineral; but it has not suffered the least alteration, for it may be restored to its original form by solution in water. Fire therefore does not decompose it: if maintained for some time in fusion, it is at length volatilized, but still without alteration. The most intense heat is requisite to bring it into this last state.

Muriate of soda when pure suffers no sensible alteration from air; it rather becomes dry than acquires moisture. It never indeed attracts moisture but when it contains a mixture of muriates with earthy bases, such as *sel de gabelle*.

It dissolves very readily in water: three parts of the fluid are sufficient to maintain one of this salt in solution. Three ounces and an half of water will entirely dissolve an ounce of the salt. Boiling water does not dissolve it in a greater proportion than cold water; only the solution is rather sooner effected with the help of heat. A very slow evaporation is requisite to give this salt in crystals. The crySTALLIZATION begins with the

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formation of a number of small points on the surface of the liquor, which are gradually united in a pellicle, more or less thick; instead of being cubic, the crystals are sometimes square hollow pyramids, resembling hoppers. Rouelle the elder, who paid the greatest attention to all the phenomena of this crystallization, observed the hoppers to be formed in the following manner. When a cube is formed, the little solid sinks a short way beneath the surface of the water; a second is soon formed, and connected with the first on one of its sides; and the same phenomenon takes place on the three other sides of the cube. This aggregation of cubic crystals naturally produces hollow inverted pyramids. When these are large they sink to the bottom. If the salt dissolved was very pure, what remains of the water after it has been evaporated till it would afford no more crystals, is entirely without any saline matter. The water of the sea and of salt springs always contains salts with an earthy base. The earth may be precipitated by soda, as we shall have occasion to mention when speaking of earthy neutral salts. Such is the method used for obtaining muriate of soda in a state of great purity.

Muriate of soda appears to contribute to the fusion of glass. It constantly occupies the upper part of the pots in which this matter is melted, and constitutes the greatest part of glass-gall.

It is used for vitrifying the exterior surface of certain pottery wares, and giving them a kind of cover, by melting down part of their substance with the force of heat communicated through the salt. This is easily effected by throwing a certain quantity of muriate of soda into the furnace. It is volatilized, and by that means spread over the surface of the earthen ware,

which, by its intense heat, it causes in part to melt. This is the English way of glazing.

Siliceous earth does not alter this salt though it appears to promote its fusion.

Pure clay acts with much less force on muriate of soda than on nitres. When distilled with this salt, it affords but a very small quantity of a weak phlegmatic acid. Distillers of aquafortis, it is true, obtain in this manner the muriatic acid called *spirit of salt*: but they make use of Gabel salt for the purpose; and it contains various muriates with an earthy base; besides, the clay which they use is very impure, and of a deep colour.

According to Bergman's experiments, barytes decomposes muriate of soda, as well as the other alkaline salts. Neither lime nor magnesia produces any alteration on muriate of soda. Perhaps these two salino-terreous substances, in combination with the carbonic acid, might separate the component principles of muriate of soda by a double elective attraction.

Caustic potash decomposes muriate of soda, having a greater affinity than soda with its acid. A solution of muriate of soda mixed with potash gives by evaporation muriate of potash, and the mother water contains pure insulated soda.

Acids act in a very distinct manner on muriate of soda. When concentrated sulphuric acid is poured on this salt, it causes a very considerable motion and a very lively heat. A violent effervescence is observed on the occasion*, which arises from the disengagement

* Effervescence is as observable in this operation as in the union of the same acid with lime and alkalis saturated with carbonic acid. It takes place, therefore, whenever any body separated from a state

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gement of the muriatic acid under the form of gas. This aeriform acid may be distinguished after it has escaped into the atmosphere, as it forms a white vapour with the water in the air, and has, when the vapour is very much diluted, a pungent smell not unlike that of saffron. A considerable quantity of muriatic acid gas may be obtained by performing the operation with a pneumato-chemical machine provided with mercury. Glauber was the first who observed that the acid of marine salt might be obtained by decomposing the salt with sulphuric acid, and described the process for obtaining it; on which account this has received the name of *Glauber's spirit of salt*. It was in examining the residue of this operation that he discovered his admirable salt to which we now give the name of *sulphate of soda*.

Almost all writers on the subject direct the distillation of this salt to obtain the muriatic acid, to be performed by putting a quantity of it into a tubulated stone-retort, and pouring in at the orifice half its weight of concentrated sulphuric acid: A considerable quantity of acid vapour is immediately disengaged, which passes by the extremity of the retort into two balloons prepared to receive it: One of these vessels has a little hole to let the vapours escape so that they may not burst the vessels. In this operation, as well as in the distillation of the nitrous acid, a considerable quantity of the purest muriatic acid is lost,—escaping in a gaseous form through the hole of the balloon;

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of combination is volatilized under a gaseous form: and it may be produced by the carbonic, the muriatic, the nitric, the sulphureous, and the fluoric acids, &c. It must not be ascribed to the disengagement of air. A,

loon; and the vapours of this acid being so very corrosive, are exceedingly troublesome to the operator. To obviate in part this inconvenience, M. Baumè puts a quantity of water into the retort; and the water being volatilized in the balloon, absorbs part of the muriatic acid gas: But as the water is much less volatile than the acid, there is still a considerable quantity of the acid lost. Mr Woulfe has found means to obviate all of these inconveniences, and to procure the muriatic acid in the strongest and most concentrated state of which it is capable, by an expedient directly contrary to M. Baumè's. Instead of volatilizing the water to make it absorb the vapours of the muriatic acid, he causes the gas to pass through that liquid by the apparatus which we described under the article of nitre.

For every two pounds of muriate of soda and one of the concentrated sulphuric acid that are mixed in the retort, eight ounces of distilled water are put into the collateral bottles. The muriatic acid gas is conducted through the tubes into the water in the bottles, and there dissolved. The water, as it combines with the gas, is heated almost to ebullition, and absorbs a quantity equal to itself in weight. When fully saturated it ceases to absorb the gas and becomes cold; but the gas passing into the second collateral bottles, is again immersed in the water which they contain, and heats and saturates it.

This very ingenious process being perfectly consistent with the known properties of the muriatic acid gas, possesses a number of advantages. 1. It secures the operator from the inconveniencies to which he is exposed when the acid is diffused through the open air. 2. It prevents the very considerable loss of the acid which was unavoidable in M. Baumè's process. 3. It

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gives the muriatic acid in a stronger, more concentrated, and more fuming state than we could possibly have it otherwise. 4. The acid obtained this way is extremely pure, being entirely formed of gas that has been dissolved in water. It is on this account extremely white; whereas that which was formerly obtained in the laboratory was always of a citron colour; a circumstance which even led chemists into a mistake, for they considered this colour as a characteristic property of the acid. That portion of the liquid acid which is in this process condensed in the receiver is yellow, and contaminated with extraneous matters conveyed into it by the water of the mixture, as happened to the whole of what was obtained in the old way. 5. The new method directs the operator what strength of fire to use, and how to conduct his operation by the slower or quicker passage of the gaseous muriatic acid through the water in the bottles. 6. Lastly, What is of more importance than any of its other advantages, it enables us to determine the precise quantity of acid contained in any neutral salt, as not a particle of the acid separated is lost.

The nitric acid likewise decomposes muriate of soda; but, being volatile, it ascends and unites with the acid of this salt. From that union there results the mixed acid known by the name *nitro-muriatic acid* or *aqua regia*.

Baron has discovered that the boracic acid, with the help of heat, disengages the acid from muriate of soda. The residue, after this distillation, is genuine borax of soda in a very pure state.

Neither the carbonic nor the fluoric acid acts in any distinct manner on muriate of soda.

None of the neutral salts hitherto described by us

acts upon this salt. When the sulphates and the nitrates of potash and soda and muriate of potash are dissolved in the same water with muriate of soda, each of these salts is crystallized by itself, and in its own way. Muriate of soda is among the first which are separated in the progress of the evaporation, and it mixes with a little of the sulphate and muriate of potash; but the sulphate of soda and nitrate of potash remain longer in solution, and are crystallized by the cooling of the liquid. On this account, in Lorraine, the mother water, from which marine salt has been obtained, is put into vessels, and stirred while it cools, with staves for the purpose; which causes the sulphate of soda to crystallize in a confused manner, in small needles, resembling those of genuine Epsom salt, or sulphate of magnesia.

The uses of muriate of soda are extremely various: It is employed, 1. For glazing some kinds of earthen ware by occasioning a slight fusion of their exterior surfaces. 2. By glass-makers, for whitening and purifying glass. 3. In assaying metal ores, as a flux to the matters of which the scoriæ are formed, to facilitate the precipitation of the metals, and to defend them from the contact of the atmosphere, so that they may suffer no change from the air.

At present we find it necessary to apply it to a purpose of still more importance than any of these,—for the extraction of soda, which is becoming every day more scarce, and is of essential use in many of the arts. Several people in England possess the secret of obtaining soda from marine salt in the great way*, and practise it in considerable extent.

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Some chemists have thought litharge capable of decomposing muriate of soda by simple maceration and cold. It would appear that, in consequence of its containing carbonic acid capable of attracting soda, and forming with the muriatic acid an insoluble salt, easily separable from the alkaline lixivium, it must act by a double elective attraction; but the experiments which I have made on this point convince me that the process is inadequate to the purpose. Scheele observed, that iron immersed in a solution of muriate of soda is coated with soda saturated with carbonic acid. He treated sulphate and nitrate of soda in the same manner, with the same success. He discovered, that if quicklime were mixed with muriate of soda, and the mixture deposited in a damp cellar, it afforded an efflorescence of soda and calcareous muriate. This fact was first communicated to the public by Cohausen in the year 1717, M. de Morveau has proved, that these decompositions are effected by means of the carbonic acid; for if a solution of sulphate and muriate of potash be poured upon lime-water precipitated by the carbonic acid, it becomes clear and transparent; but when water containing carbonic acid is poured on a solution of those salts mixed with lime-water, no precipitation takes place. These facts are so many *data*, on which we must proceed in attempts to obtain soda from marine salt, and form extensive establishments for the purpose.

Muriate of soda is used as seasoning to the articles of our food, and corrects their insipidity. It likewise facilitates digestion, by beginning the putrid alteration of

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not practised in England to such extent as M. Fourcroy seems to think.

the substances we use for aliment. Though it be fully proved by the experiments of Pringle, Macbride, &c. that when mixed in a pretty large proportion with animal substances, it retards putrefaction, and is powerfully antiseptic, like most other saline matters; yet it acts in a very different manner when mixed with the same substances in a very small proportion, causing them to pass more readily into a state of putrefaction. This is proved by the experiments of the author of the *Essays on the History of Putrefaction*, and M. Gardane's experiments.

This salt is not less useful in medicine. In apoplectic and paralytic cases, &c. it is put into the mouth, and used externally in baths as an excellent stimulant. In most cases it is a powerful discutient. It is strongly recommended by Ruffel (*de Tabæ Glandulari*) for lymphatic tumours, occasioned by a scorbutic habit. I have myself prescribed it successfully for several diseases of that kind. It is purgative when administered in doses of several drams. As the most impure salt is commonly used on all of these occasions, its effects are in part to be ascribed to the calcareous and magnesian muriates which it contains.

Species VII. *Borax of Soda, or Super-saturated Borate of Soda* *.

BORAX of soda, or common borax, is a neutral salt, formed

* Hitherto we have begun with examining the neutral salts formed by the union of the acids with potash. But, in speaking of those into which the boracic acid enters, we are obliged to begin with that which has soda for its base, for it is the only one with which we are well acquainted,

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formed by the combination of the boracic acid with soda. We get this salt from the East Indies; but its history is very little known. We know not certainly whether it be a product of nature or of art *. If the discovery of the boracic acid existing in a state of solution in the waters of several lakes in Tuscany, a fact which we mentioned in the history of that acid, give us reason to think borax a product of nature, a variety of facts which we shall hereafter mention, concur to show that this salt may be also formed by certain artificial processes, as well as nitre.

Borax of soda appears in commerce in three different states. In the first, it is crude borax, *tinckal* or *bryfocolle*. This we get from Persia; it is in greenish masses which feel greasy, or in opaque crystals, coloured like green leeks, which are prismatic figures of six faces, terminating in irregular pyramids. There are even two kinds of these greenish crystals, differing from each other in size. This salt is very impure, a great many extraneous substances being intermixed in it.

The second species is known by the name of *China borax*. It is rather more pure than the former: it appears in the form of small plates, or in masses irregularly crystallized, and of a dirty white colour: it displays the beginnings as it were of prisms and pyramids confounded together without any symmetrical arrangement. The surfaces of those crystals are covered over with

* Kirwan, in his mineralogy, page 206. informs us, that it is dug out of the earth in the kingdom of Thibet, in a crystalline form. In the Philosophical Transactions for the year 1787, we are informed by a letter from Mr Blane, dated at Lucknow, that the borax of Thibet is formed in a certain valley in that country, by the co-operation of snow and the waters of a lake in the middle of the valley with a saline matter which abounds over the valley.

with a white dust, which is thought to be of an argillaceous nature.

The third species is Dutch or refined borax. It appears in fragments of crystals, transparent and tolerably pure : pyramids with a number of faces are observed in it ; but their crystallization appears to have been interrupted. This form affords a certain indication of the manner in which the Dutch purify this salt ; it is by solution and crystallization.

Lastly, It is prepared at Paris by Messrs Lesguillers, druggists in Lombard Street : and their purified borax is no way inferior, perhaps even superior, in purity to the Dutch borax.

Besides these four kinds of borax, M. la Pierre apothecary in Paris has imagined it to be formed in a mixture of soap-suds with dirty kitchen-water, which a certain individual preserves in a kind of ditch, obtaining from it at the end of a certain time genuine borax in beautiful crystals. But this fact, though first communicated to the public ten years since, has not received confirmation.

We are still ignorant therefore in what manner borax is formed ; only it appears to be produced in stagnant waters containing fat matters. Some authors assure us, that it is artificially composed in China, by mixing in a trench grease, clay, and dung, in alternate layers, watering this collection of matters at proper times, and leaving it untouched for several years. At the end of this time, by forming those matters into a lixivium, and evaporating the lixivium, crude borax is obtained. Others would persuade us, that it is got out of water filtered through copper ore. M. Baumé positively asserts that the former of these processes

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Purified borax appears under the form of six-sided prisms, two of them larger than the rest, with trihædral pyramids. It displays a great many varieties in its crystallization. Its taste is stiptic and urinous. It communicates a green colour to syrup of violets, on account of its containing an extraordinary proportion of soda. We leave it in possession of the name of borax, in order to distinguish it from genuine *borate of soda*, which is saturated with the boracic acid: we likewise call it *borax super-saturated with soda*, to indicate the nature of the combination.

When exposed to the action of fire, the water of its crystallization causes it to melt with great rapidity; it gradually loses that water, and swells to a considerable bulk. It is then in the form of a light, porous, and very friable mass, known by the name of *calcined borax*. The cause why borax of soda increases in bulk, and assumes a lamellated porous form, on being calcined, is, that the water which is disengaged into a vaporous state, raises to the surface a portion of the saline substance half dried, and in light thin pellicles; and the bubbles in which it rises, making their way out at the surface, the pellicles become entirely dry, and are arranged one above another with interstices between them. Calcination produces no alteration on borax of soda, as to its component parts: it loses, in undergoing this process, nothing but the water which mixed with it in crystallization, nearly in the proportion of six ounces to the pound. We can restore to it its original form by dissolving it in water, and causing it to crystallize anew. But if after it has been calcined, we expose it to a continued heat, it melts on becoming red-hot into

a very fusible transparent greenish glass; which is fulfilled by exposure to the air, and melts in water. Even fusion produces no change of nature on borax; we can cause it to resume its original appearance, with all its peculiar properties, by solution and crystallization.

Air effects no alteration on this salt: it makes it effloresce indeed at the surface by depriving it of part of the water of its crystallization. But this efflorescence does not take place in the same manner on all the several kinds of purified borax of soda. The borax of China gives a much slighter efflorescence than Dutch borax. Dutch borax likewise gives a more copious efflorescence than the borax purified in Paris. This slight difference depends no doubt on the different processes adopted for purifying it, on the manner in which it is caused to crystallize, the quantity of water which its crystals contain, according as they have been more slowly or quickly, and perhaps too on the different proportions of soda, and the boracic acid which enter into its composition.

Borax of soda dissolves very readily in water: twelve parts of cold water are necessary to dissolve one of this salt; half that quantity of boiling water will produce the same effect. It is obtained in crystals by cooling the solution, but the most beautiful and regular crystals are formed in the mother-water, when it is left to evaporate slowly, with the ordinary temperature of the atmosphere.

Borax of soda serves for a flux to siliceous earth, and joins with it to form a very fine glass. It is used in the preparation of artificial precious stones.

It likewise causes clay to vitrify, but with much more difficulty, and much more imperfectly. This is

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We are rather unacquainted with the action of pure barytes and magnesia on borax of soda. Bergman, however, ranks those two substances before the alkalis in the tenth column of his table of affinities; which shows that he thinks them capable of decomposing this salt. But in his dissertation, he says, that the affinities of ponderous earth and magnesia with the boracic acid are not yet exactly known.

Lime has actually a greater affinity than soda with this acid. Lime-water precipitates a solution of this salt; but to make it decompose entirely, we must boil quicklime and borax of soda together: an almost insoluble saline combination of lime with the boracic acid is then deposited, and the caustic soda is left in solution in the water.

Potash appears to decompose borax of soda as well as all other neutral salts with a base of mineral alkali. Ammoniac produces no sort of alteration on this salt.

The acids act on borax in a very distinct manner. If into a boiling solution of borax of soda you pour a quantity of concentrated sulphuric acid, taking care to give the liquor a very small excess of the acid, you may obtain from this mixture by filtrating and cooling it a very copious precipitate in small bright scales. This precipitate is boracic acid, and by washing it in distilled water, and drying it in the air, it is rendered very pure. By evaporating the solution thus prepared and leaving it to cool, we obtain from time to time new quantities of boracic acid. At last, the product is sulphate of soda, formed by the union

nion of the sulphuric acid made use of on the occasion with the alkaline base of borax.

The nitric and the muriatic acids decompose borax of soda in the same manner, because they, as well as the sulphuric acid, have more affinity with soda than the boracic acid has. The last evaporations of these mixtures afford nitrate or muriate of soda. The discovery of the boracic acid seems to belong to Beccher, but has been usually ascribed to Homberg, he having, in the Memoirs of the Academy for the year 1702, given the first accurate description of a process for obtaining it. That chemist observed this salt to be sublimated in the distillation of a mixture of sulphate of calcined iron with borax of soda and water. Imagining the first of these matters to contribute greatly to its formation, he gave it the name of *narcotic volatile salt of vitriol*. Lewis Lemery, eldest son to the famous Nicholas Lemery, made many experiments on borax of soda, and discovered in the year 1728, that the boracic acid, then called *sedative salt*, might be obtained from it by means of the pure sulphuric acid, and that the muriatic and the nitric acids likewise separated it; but sublimation was the process which he always used. We are indebted to Geoffrey the younger for the first complete analysis of borax. In the year 1732, he proved that the boracic acid might be obtained by evaporation and crystallization; and by examining the residue which remained after these operations, found soda to be one of the principles of borax.

Baron's experiments on this salt, which were laid before the academy in the years 1745 and 1748, added two important facts to these discoveries. The first, that vegetable as well as mineral acids decomposed borax of soda. The second, that genuine borax may

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be formed by uniting the boracic acid with soda. The last of these facts proves that the acid is entirely formed in the salt, and that its formation is in no degree owing to the acids employed to decompose the salt.

The fluoric, and even the carbonic acid though one of the weakest, appears to be capable of decomposing borate of soda, and separating the boracic acid. This last acid unites readily with borax of soda, its alkaline base requiring to be fully saturated with rather more of the boracic acid than a quantity equal to the whole weight of the borax. Bergman is even of opinion that this salt is not fully saturated nor properly neutral, and that alkaline properties still continue to predominate in it till such time as it receives this additional quantity of boracic acid. The properties of this neutral salt, when thus saturated, have not as yet been particularly examined.

None of the alkaline neutral salts, whether sulphuric, nitric, or muriatic, acts in any manner on borax of soda.

This salt acquires a reddish colour when melted with combustible matters, such as charcoal; but we know not yet what alteration it suffers from those matters.

Borax is of great utility in many of the arts. In glass-making, and the assaying of metals, it is used as an excellent flux. It is used in soldering metals to make the mixture run, which is designed for the solder; and it at the same time softens the surfaces of the metals to be united, and defends them from being calcined by the action of the air. It was formerly much used in medicine, but is now gone quite out of use.

Species VIII. *Borate of Potash.*

WE give the name of *borate of potash* to the combination of the boracic acid with potash. It is well known that these two saline substances readily unite, and that from their union there results a neutral salt, resembling borax of soda. Of this kind is the residue of nitre of potash, decomposed by the boracic acid. M. Baumé says, that this residue appears in the form of a white half-melted mass, which when dissolved in water affords small crystals. Borate of potash is therefore fusible, soluble, and susceptible of crystallization, and pure acids decompose it as well as borate of soda. We know nothing more certain of this salt; it should be examined in the same manner as borate of soda. Baron knew the possibility of producing this salt by a direct combination of the boracic acid with potash; he has even distinguished it accurately from common borax, or borax with a base of soda; but not a word has he said concerning the peculiar properties of borax of potash.

Species IX. *Fluate of Soda.*

ACCORDING to the system of nomenclature to which we have conformed from the beginning of this work hitherto, the name *fluat* of soda denotes the combination of the fluoric acid with potash. This neutral salt has, as yet, undergone but a very slight examination—by Messrs Scheele and Boullanger. According to those two chemists, it always appears in a gelatinous form, and is never crystallized. According to Scheele,

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it becomes, when dried and melted, acrid, caustic, and gelatinous. He compares it in that state to liquor of flints. It appears that fire disengages the fluoric acid; and that the siliceous earth with which it is always impregnated during its preparation, then melts into a soluble glass with the help of the potash.

Fluate of potash dissolves very readily in water. It always retains so large a proportion of that fluid, that it is impossible to make it assume a crystalline form. When it is well saturated, a solution of it produces no alteration on syrup of violets.

We know not in what manner either siliceous, argillaceous, or barytic earth or magnesia, affects this salt.

According to Scheele and Bergman, lime has more affinity than potash with the fluoric acid. Throw fluuate of potash into lime-water it is instantly decomposed: lime unites with the fluoric acid, forming an insoluble salt, which takes away the purity of the liquor, and is fluuate of lime. We shall afterwards see that lime likewise decomposes neutral salts formed of the carbonic acid with fixed alkalis. We have already seen that lime-water precipitates borax of soda; therefore the fluoric is not the only acid which has a greater affinity with that salino-terreous substance than with the fixed alkalis.

The concentrated sulphuric acid decomposes fluuate of potash by disengaging its acid; which, according to M. Boullanger, appears in the white vaporous form, and exhales the odour peculiar to the muriatic acid. When this experiment is made in an apparatus proper for distillation, we obtain the fluoric acid, just as we obtain the acids contained in nitre of potash, and mu-

riate of soda when we decompose them with the sulphuric acid.

No inquiry has hitherto been made concerning the action of the nitric and the muriatic acids, or of the known neutral salts, on fluuate of potash. This salt is in other respects little known, and is applied to no use.

Species X. *Fluuate of Soda.*

THIS is a proper enough denomination for the neutral salt formed by the saturated combination of the fluoric acid with soda. This, like the foregoing salt, has been but very little examined. Nobody but Messrs Scheele and Boullanger has said any thing about it; and they differ in their opinions, as we are just going to see.

Scheele asserts, that a combination of soda with the fluoric acid forms a jelly like the preceding salt. Boullanger, on the contrary, says, that the combination affords very small, hard, brittle crystals, of an oblong square figure, a bitter taste, and somewhat stiptic. This salt decrepitates on burning coals like muriate of soda; it dissolves in water, but not readily.

Lime-water decomposes this salt as well as fluuate of potash. The sulphuric disengages the fluoric acid from this salt with effervescence, causing it to rise, like the muriatic acid, in a white vapour of a pungent smell.

From this short account of this salt, the reader may perceive that it is not better known than the last.

Species XI. *Carbonate of Potash.*

THE last two neutral salts which we have to examine, are combinations of the carbonic acid with fixed alkalis.

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These substances were never before reckoned among the neutral salts: but we shall immediately see that they are true neutral salts.

What we call *carbonate of potash*, is a neutral salt resulting from a saturated combination of carbonic acid with potash. Some modern chemists call it *mephitic tartar*, aerated *vegetable alkali*, &c. This saline substance was always taken for pure alkali, till Dr Black's experiments showed it to be a neutral salt. Its old name was *fixed salt of tartar*, because it was obtained by the incineration of tartar of wine. It was considered as an alkali, because it possesses some of the properties of those salts. It does indeed convert syrup of violets to a green colour; but borax and several other neutral salts possess the same property: besides, it neither destroys nor weakens the colour of violets like potash. It has an alkaline taste; but the same is distinguishable in borax: only it was distinguished from alkali of soda by its power of attracting the moisture of the air with great rapidity, and its not being susceptible of crystallization. When thus moistened in the air, it received the name of *oil of tartar per deliquium**. But fixed salt of tartar possesses these two properties only because it is not a perfect neutral salt. Containing still a certain quantity of potash not saturated with carbonic acid, this excess of alkali renders it deliquescent. At present, this salt is obtained in a state in

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which

* Bohnius relates, that evaporating oil of tartar slowly, by a moderate heat, he obtained, under a saline pellicle, beautiful crystals, which, though exposed to various temperatures, remained six years unaltered (*Dissert. Physico-Chem.* 1666.) M. Montet, a celebrated chemist of Montpellier, who was certainly unacquainted with Bohnius's discovery, has invented a process for crystallizing this fixed salt of tartar. *Academ. des, &c.* 1764, p. 576.

which it is very susceptible of crystallization, and attracts no moisture, but rather effloresces. The Duke de Chaulne, who has paid much attention to this object, prepares this salt by exposing a solution of potash, either caustic or containing a little of the carbonic acid, in a place full of that gaseous acid, as in the upper part of a barrel of beer when it is fermenting. The alkali seizes as much of the carbonic acid as it can absorb, and is regularly crystallized. Its crystals are quadrangular prisms, terminating in very short pyramids with four faces.

Carbonate of potash has an urinous taste, but much weaker than that of the caustic vegetable alkali; for in medicine it is given as a discutive in doses of several grains. This neutral salt is very subject to alteration from fire; it melts easily, and is pretty quickly reduced to an alkali. If it be distilled in a retort with a receiver, and a pneumatological apparatus with mercury fitted to it, the products obtained are, the water of its crystallization, and its acid in an aeriform state. The potash, after this operation, remains in an irregular mass, still retaining, however, a small portion of the acid, which cannot without the greatest difficulty be extracted from it by fire. According to Bergman's analysis of it, carbonate of potash, when saturated with the acid, and regularly crystallized, to which he gives the name of *aerated vegetable alkali*, contains in the quintal twenty parts of the acid, forty-eight of pure alkali, and thirty-two of water. But it is to be observed, that carbonates are more liable than other neutral salts to vary in the quantity of the acid. Yet, as this salt never furnishes regular crystals but when it is fully saturated, Bergman's calculation deserves to be considered as sufficiently accurate.

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Carbonate of potash, when fully crystallized, suffers no alteration from air; its crystals neither deliquesce nor effloresce, but remain transparent. This salt, when so pure as to possess this property, being of use in many experiments, it may be proper to let the reader know that it is prepared in the following manner: By exposing a lixivium of common potash, very pure and white, and separated from the sulphate of potash which it usually contains, in a shallow dish, in the upper part of a beer barrel; and the process is the sooner completed, if the potash be continually stirred or poured out of one vessel into another; and if it be thus kept in contact with the carbonic acid produced by fermentation, till such time as it deposite beautiful crystals of carbonate of potash.

This salt dissolves readily in four parts of cold water, and a rather smaller quantity of warm water will maintain it in solution; it produces cold as it unites with that fluid. That property which distinguishes neutral from simple salts sufficiently determines the difference between carbonate of potash and pure or caustic potash. It is crystallized by evaporation and cooling conjunctly. When the solution is too much concentrated, it takes the form of an irregular mass,—which often happens in the laboratories.

This salt, as well as potash, serves as a flux to vitrifiable earths; because fire reduces it to an alkali by expelling the carbonic acid. Besides, when this salt, with a mixture of sand, is violently heated in a crucible, a lively effervescence may be observed at the instant of vitrification; and that effervescence is owing to the disengagement of the carbonic acid. This fact shows that siliceous earth cannot enter into combination with an alkali saturated with this acid, and that

the acid escapes when the vitreous combination takes place. This effervescence attends so invariably the combination of these two substances, that Bergman proposes to try filiceous earth by means of the blow-pipe, with carbonate of potash, as no other earth exhibits the same phenomenon when heated with this salt.

Clay does not act at all on carbonate of potash; but the salt reduces that earth to a vitreous frit, though not quite so easily as caustic potash. Barytes deprives this salt of the carbonic acid.

Lime likewise decomposes it, having a greater affinity than potash with the acid. Lime-water poured into a solution of carbonate of potash, gives a precipitate of an almost insoluble salt, produced by the combination of lime with the carbonic acids; and the pure or caustic alkali remains dissolved in the water. In pharmacy, this process is made use of for the preparation of the *lapis causticus*, which is nothing but fixed vegetable alkali rendered caustic by lime. Modern discoveries have shown, that Lemery's process for preparing the *lapis causticus*, though followed by many pharmacopœiæ, is very defective. It consists in mixing two pounds of ashes obtained by the combustion of the husks of grapes with lees of wine*, with a pound of quicklime, immersing the mixture into sixteen pounds of water, filtering it, evaporating this lixivium in a copper vessel, melting the residue in a crucible, and pouring it out upon a plain surface. The product obtained by this operation is merely a dirty alkali not very caustic, and containing copper.

Bucquet,

* Those ashes contain a great deal of vegetable alkali or carbonate and sulphate of potash. A.

Bucquet, sensible of the disadvantages of this process, has given one, more tedious and expensive indeed, but much more certain and advantageous, especially for preparing very pure potash, which is so necessary in chemical experiments. Take two pounds of very strong quicklime; pour a little water upon it to reduce it to powder; add a pound of fixed salt of tartar, and pour upon it as much water as may be sufficient to form it into a paste: When this mixture becomes cool, add to it water to the quantity of sixteen pints, and put the whole into a linen cloth lined with paper; about twelve pints of a clear liquor will pass through this strainer, and the remainder is to be washed with four pints of boiling water to take away all the alkali. This liquor gives no effervescence with acids: but the best test for trying its causticity is to observe whether it clouds lime-water; for if it contain the smallest portion of carbonic acid, it will infallibly produce that effect. But as, after this first process, it still gives a precipitate with lime-water, when very pure alkali is wanted for nice experiments, the lixivium may be treated with two additional pounds of quicklime. It then passes very clear through the strainer, and becomes so caustic as not to alter the transparency of lime-water. When the alkali is evaporated by fire in the open air, that salt absorbs the carbonic acid contained in the atmosphere; therefore, to obtain it in a dry form, and very pure, we must evaporate the liquor in a retort. But this very tedious process is not necessary for producing the *lapis causticus*; for if alkali be of such strength as to corrode the surface of the skin, it is sufficient for the purposes of that preparation. But as dry solid potash, in a state of high purity, is necessary in many experiments, I must here observe, that

the caustic alkaline lixivium must be evaporated in close vessels, and that the fire must be very cautiously managed, because the evaporation is attended with considerable difficulty, in regard to the density which the liquor assumes towards the end of the process. The fixed alkali is very white, and does not effervesce with acids, nor destroy the purity of lime-water.

Magnesia does not act on carbonate of potash; for the carbonic acid has a greater affinity with fixed vegetable alkali than with that salino-terreous substance.

The sulphuric, the nitric, the muriatic, and the fluoric acids, decompose carbonate of potash by combining with the fixed alkali, and separating the carbonic acid with effervescence. The acid may be collected under water or mercury. It is distinguishable by the four following characteristics: it is more ponderous than air; it extinguishes lights; reddens tincture of turnsol; and precipitates lime water.

The boracic acid seems incapable of separating the acid from carbonate of potash cold; but when hot, it effects it with great ease.

The neutral salts which we have examined neither suffer any alteration from carbonate of potash, nor produce any such effect upon it.

This salt abounds in nature. It is often found in vegetables, completely formed, and is constantly obtained by the incineration of those organic bodies; as we shall have occasion to show when we come to speak of the vegetable kingdom. Burnt tartar affords it in the greatest abundance. It is also prepared by the detonation of nitre of potash.

Carbonate of potash is much used in the arts. In medicine, it is administered as an aperient and discutient, in obstructions of the mesentery and the urinary passages.

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Species XII. *Carbonate of Soda.*

THIS salt, like the foregoing, was formerly thought an alkali. It is, however, a combination of the carbonic acid with mineral alkali. This seems to be the salt which the ancients called *natrum*. It is usually called *salt of soda*, because it may be obtained pure and regularly crystallized by evaporating a lixivium of common soda. Marine alkali is likewise distinguished from vegetable fixed alkali, by its being susceptible of crystallization and efflorescence, which is owing to its being completely saturated with carbonic acid in its ordinary state.

Carbonate of soda has an alkaline taste; it communicates a green colour to syrup of violets, but does not, like caustic soda, finally alter its colour. Its taste is urinous, but not burning, and much weaker than that of pure marine alkali.

This salt is naturally purer than carbonate of potash, and has been long known to be susceptible of crystallization; a property which may be considered as forming a general distinction between neutral and simple salts. Its crystallized form is owing to its containing almost always the quantity of carbonic acid necessary to its saturation and crystallization.

This salt, when hastily crystallized, exhibits rhomboidal plates, disposed obliquely one over another, like tiles on the roof of a house. When slowly crystallized, it assumes the form of rhomboidal octohædrons, with pyramids

pyramids truncated near the base, or solid decahædrons, with two acute and two obtuse angles.

This salt generally melts easier than carbonate of potash; for which reason it is used in preference to it in the glass-houses. It loses most part of its acid by heat, but still retains a little. Bergman has found, by an exact analysis, that an hundred parts of carbonate of soda, which he calls *aerated mineral alkali*, contain sixteen parts of the acid, twenty of pure alkali, and sixty-four of water:—so that more of the acid is requisite to saturate soda than to saturate potash; and the crystals of the former retain just twice as much water as those of the latter. It is to this extraordinary quantity of water that carbonate of soda owes its crystallizing with such facility and regularity, as well as its property of efflorescing.

Carbonate of soda is more soluble than carbonate of potash. It dissolves in two parts of cold or one of boiling water. It crystallizes by cooling, but gives much more regular crystals by slow evaporation.

When this salt is exposed to the air, it crumbles down very readily into dust; for the air deprives it of the water of its crystallization: But it is not altered by this efflorescence; for we can restore to it its primary form by solution in water.

It contributes greatly to the fusion of vitrifiable earths, and forms with them a glass less liable to alteration than that which is in part composed of carbonate of potash, to which it is for that reason preferred in the glass-houses. It has been observed, that when sand unites with this salt, it escapes with a very observable effervescence, agreeably to what we have remarked of carbonate of potash. It has no more influence on clay than the last salt.

Barytes,

Barytes, as well as quicklime and lime-water, decomposes carbonate of soda in the same manner as carbonate of potash, and separates the pure caustic mineral alkali. A solution of this salt poured into lime-water produces a precipitate; an effect which is never produced by caustic soda. When pure caustic soda is wanted for nice chemical experiments, recourse must be had to the same process which we described above for preparing the *lapis causticus*.

Carbonate of soda, as well as carbonate of potash, may be decomposed by the sulphuric, the nitric, and the muriatic acids, &c. The carbonic acid may be obtained from it by collecting it into a glass filled with water or mercury.

In Egypt, this salt is found entirely formed at the surface of the earth, as well as in several other places. It is likewise found in the ashes of sea-weeds, but not completely saturated with the acid. To render it more perfectly neutral, it must be directly combined with the cretaceous acid, either by shaking it over some liquor in a state of fermentation, or by receiving into a solution of it a portion of the carbonic acid, separated from chalk by the sulphuric acid. It may be also produced by wetting the sides of a vessel with a solution of soda, and then pouring into the vessel a quantity of carbonic acid: the mouth of this vessel is then to be covered with a wet bladder; and at the end of a few hours, the combination is found to be effected,—for the bladder is emptied by the absorption of the carbonic acid, and the sides of the vessel are covered with the salt in regular crystals.

Carbonate of soda may be applied to the same purposes with carbonate of potash. It is much more used in soap and glass manufactories, &c. &c. We should therefore

therefore endeavour to procure it in greater quantities, and to extract it in the great way from muriate of soda. We have seen that litharge, which some chemists pretend to be adequate to this effect, does not properly decompose that salt. We have also taken notice of Scheele's having discovered a more entire decomposition of muriate of soda, effected by quicklime and iron, with the help of atmospheric air, and the carbonic acid which it contains. We see that a greater proportion of this acid than what usually exists in the atmosphere, is requisite to promote this decomposition by exerting its attractive force on the soda.

CHAP.

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CHAP. VI.

Genus II. *Imperfect Neutral Salts, with a Base of Ammoniac, or Ammoniacal Salts.*

AMMONIACAL salts are formed by the combination of an acid with volatile alkali, or ammoniac. Their taste is generally urinous: all of them are more or less volatile, and easier of decomposition than perfect neutral salts. We know of six kinds or species of ammoniacal salts:—ammoniacal fulphate; ammoniacal nitrate; ammoniacal muriate, or sal ammoniac properly so called; ammoniacal borate; ammoniacal fluuate; and ammoniacal carbonate.

Species I. *Ammoniacal Sulphate.*

AMMONIACAL fulphate, formerly called *ammoniacal vitriolic salt*, or *ammoniacal vitriol*, results from a saturated combination of the sulphuric acid with ammoniac. It is called *secret ammoniacal salt of Glauber*, because that chemist was the first who discovered it.

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This salt, when very pure, appears under the form of needles, which when carefully examined are found to be flattened prisms of six faces, two of them very large, and terminating in six-sided pyramids more or less irregular: but this form varies almost always either more or less from what we have described. Sometimes this salt appears in quadrangular prisms; and I have often obtained it in very thin square plates. Its form, as in other instances of crystallization, seems to depend on the manner in which the crystalline laminae are deposited; which is either on their largest faces, their edges, or their angles.

The taste of this salt is bitter and urinous; it is pretty light, and very friable.

As it contains, in crystals, a good deal of water, even a moderate fire instantly liquefies it; but it becomes gradually dry, in proportion as the water which it contained is evaporated. When brought to that state, it melts, according to M. Bucquet, as it begins to become red-hot, without volatilizing; but M. Baumé says that it is partly volatile. On repeating this experiment, I observed that part of this salt is actually sublimated, but part remains fixed in the vessels. M. Bucquet is certainly to be understood as speaking of this last part.

Ammoniacal sulphate suffers scarce any alteration from air. It does not effloresce like sulphate of soda, but rather attracts moisture.

It dissolves very readily in water: two parts of cold water dissolve one of this salt; and boiling water dissolves a quantity equal to its own weight. It crystallizes by cooling; but the finest crystals which it affords are obtained by insensible and spontaneous evaporation. It combines also with ice, which it causes to melt with

a considerable cold. It acts not at all on either aluminous or siliceous earth. Magnesia decomposes it in part, especially if time be allowed it to act, as Bergman has observed.

Lime, barytes, and the pure fixed alkalis disengage the ammoniac from this salt; and we shall find the case to be the same with regard to ammoniacal muriate. When carbonate of potash or soda is distilled with ammoniacal sulphate, a double decomposition and combination take place. The sulphuric acid combining with fixed alkali, forms sulphate of soda or potash, according to the nature of the alkali; and the carbonic acid which is disengaged, being volatilized at the same time with the alkaline gas or ammoniac, these two bodies unite, forming a peculiar ammoniacal salt, which is crystallized in the receiver. We will consider this point more at large under the history of the Ammoniacal Muriate.

The nitric and the muriatic acids separate part of the sulphuric acid from ammoniacal sulphate; acting upon it just as upon sulphate of potash and soda.

This salt has never yet been found among the products of nature. Yet M. Romé de Lille in his *Essay on Crystallography*, 1772, page 57, informs us, that, in M. Sage's opinion, the ammoniac salt produced from volcanoes is of this kind. Art produces it by a direct combination of the sulphuric acid with ammoniac, by decomposing earthy or metallic salts with volatile alkali, or lastly, by decomposing nitric, muriatic, and carbonic ammoniacal salts with sulphuric acid.

Ammoniacal sulphate is applied to no use; though Glauber has recommended it strongly for metallurgic operations.

Species.

Species II. *Ammoniacal Nitrate.*

AMMONIACAL nitrate, or *nitrous ammoniacal salt*, is, like the foregoing salt, a product of art. It is prepared by a direct combination of the nitric acid with ammoniac. Its crystals are prisms; but the number and the disposition of their faces are not well known. M. Romé de Lille says, that it sometimes crystallizes in beautiful needles pretty similar to those of sulphate of potash. But its needles are long and striated, and resemble those of common nitre much more than sulphate of potash. The taste of this salt is bitter, pungent, somewhat fresh and urinous. It is equally friable with ammoniacal sulphate. It liquefies when exposed to the action of fire; exhales aqueous vapours, becomes dry, and long before being red-hot detonizes of itself, without being in contact with any combustible matter, and even in close vessels. In the first edition of this work it was observed, that this singular property appeared to depend on the ammoniac, because the alkaline gas seems to have something combustible in its nature, and increases before extinguishing the flame of a taper. M. Barthollet having exposed a quantity of ammoniacal nitre to the action of fire in a distillatory and pneumato-chemical apparatus, and having observed the phenomena which it then exhibited with peculiar attention, discovered that it is not a true detonation which takes place on that occasion, but a rapid decomposition, by which part of the volatile alkali or ammoniac is entirely destroyed: the water obtained in the receiver contains a little nitric acid, proportioned to the quantity of the ammoniac decomposed; and the latter gives out azotic gas, or atmospheric mephitic. On weighing
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the liquid product of this operation, the quantity of water is found to be greater than what the ammoniacal nitre was known to contain; and M. Berthollet thinks this increase of the water to be owing to the combination of the hydrogene of the ammoniac with the oxygen of the nitric acid. The azotic, the other principle of this salt, which contains fix parts of it for one of hydrogene, escapes, and is collected under the glasses of the pneumatic-machine, in the form of azotic gas.

It is not known whether this salt be fusible; for its first liquefaction is owing to the water of its crystallization, and it is dissipated before it can undergo a second.

We are equally ignorant with regard to its volatility: we can form no judgment of it; for, before it can be sublimated, it swells and is decomposed.

It feebly attracts the moisture of the air; its crystals agglutinate, and form a kind of clods.

It dissolves very readily in water; it combines with ice, and melts it, producing at the same time a considerable cold. It dissolves more readily in warm than in cold water: no more than half a part of the former is requisite to maintain it in solution, and it crystallizes by cooling, but irregularly. To obtain this salt in regular crystals, recourse must be had to spontaneous or insensible evaporation.

Ammoniacal nitrate is decomposed by barytes, lime, and the alkalis, in the same manner as ammoniacal sulphate. As the alkaline gas separated by these caustic substances is very volatile and expansive, ammoniacal nitrate, as well as the other neutral salts of the same genus, may be decomposed cold by trituration with lime. But when this decomposition is attempted by

fire in close vessels, the heat must be very cautiously managed, to prevent it from catching fire.

The sulphuric disengages the nitric acid from this salt with effervescence, and combines with its base to form ammoniacal sulphate.

Carbonate of potash or soda decomposes it, and is in its turn decomposed by it. In these operations, ammoniac is sublimated in a concrete form: the sublimate we are afterwards to examine under the name of *ammoniacal carbonate*.

Ammoniacal nitre is not applied to any use.

Species III. *Ammoniacal Muriate*, or *Sal Ammoniac*.

AMMONIACAL muriate, or the saturated combination of the muriatic acid with ammoniac, was called by the ancients *sal ammoniac*; because it was procured from Ammonia, a country in Libya, in which stood the temple of Jupiter Ammon.

This salt is found in places adjacent to volcanoes. It appears in the form of an efflorescence, or groupes of needles, separate, or compacted together, generally of a yellow or red colour, and mixed with arsenic and orpiment: but no use is made of that which is procured in this way. The *sal ammoniac* employed in the arts, is prepared by a process which we are just about to describe.

The real origin of this factitious salt was unknown till the beginning of the present century, tho' it had been made use of in many of the arts from time immemorial. M. Lemère, consul at Cairo, in a letter to the

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the academy, dated 24th June 1719, first informed us how *sal ammoniac* is obtained from the foot of camels dung, which is burnt at Cairo instead of wood.

This foot is put into large round bottles a foot and an half in diameter, and terminating in a neck two inches long. These bottles are filled up with this matter till within four inches of the neck. Each bottle holds about forty pounds of foot, and affords nearly six pounds of salt. These vessels are put into a furnace in the form of an oven, so that only the necks appear above. A fire of camel's dung is kindled beneath it, and continued for three days and three nights. On the second and the third day the salt is sublimated. The bottles are then broken, and the salt taken out in cakes. These cakes, which are sent us just as they have been taken out of the bottles in Egypt, are convex, and unequal on the one side; on the middle of that side they exhibit, each a tubercle corresponding to the neck of the bottle in which it was prepared. The lower side is concave; and both are footy.

Pomet makes mention of a *sal ammoniac*, procured by the way of Holland, in truncated cakes resembling sugar loaves. Geoffrey, who was the first in France that discovered from what materials this salt is obtained, and who even guessed successfully at the process employed in Cairo for preparing it, found out that this second species of salt comes from the Indies, where it is prepared in much greater quantities than in Egypt by the same process of sublimation, but in a different form. These Indian loaves consist of fourteen or fifteen pounds each, are hollow at the bottom, and formed of various layers. The cone is truncated, because its extremity, being impure, is always broken off.

M. Baumé has established, in the neighbourhood of
Paris,

Paris, a manufactory of ammoniacal salt; in which this salt is composed, not extracted as in Egypt. M. Baumé's salt is likewise purer than the Egyptian *.

Ammoniacal muriate has a poignant, acrid, and urinous taste. Its crystals are in the form of long hexahædral pyramids: a number of them are sometimes united together in an acute angular direction, so as to exhibit the form of feathers. M. Romé de Lille thinks the crystals of ammoniacal muriate to be octohædrons bundled together. This salt is sometimes, but not frequently, found in cubic crystals in the middle of the concave hollow part of the sublimated cakes.

This salt possesses one pretty singular physical property; a kind of ductility or elasticity, which causes it to yield under the hammer, or even the fingers, and makes it difficult to reduce it to a powder.

Ammoniacal muriate is totally volatile; but a very strong fire is requisite to sublimate it. This method is applied when it is wanted very pure and entirely free of water. It is reduced to powder, put into a matras, and the vessel is then immersed half way into a sand-bath, where it is gradually heated for several hours. By this means we obtain a mass consisting of striated needles, joined to each other longitudinally. When this

* In Britain sal ammoniac is likewise prepared in great quantities. The volatile alkali is obtained from foot, bones, and other substances known to contain it. To this the vitriolic acid is added; and this vitriolic ammoniac is decomposed by common salt by a double affinity. The liquor obtained in consequence of this decomposition contains sulphate of soda and sal ammoniac. The first is crystallized, and the second sublimated so as to form cakes, which are then exposed to sale. Lord Dundonald, by an ingenious process, extracts ammoniac from pit-coal.

this operation is properly conducted, very regular cubic-crystals are often found in the midst of the loaves. But if too strong a heat has been applied, the product is only a shapeless thick and semi-transparent mass, with the appearance of having been melted.

M. Baumé has observed, that by repeated sublimations of this salt, a small quantity both of ammoniac and of the muriatic acid is at length disengaged; so that, according to that chemist, ammoniacal muriate might perhaps be decomposed by continued sublimation. This fact requires confirmation.

Ammoniacal muriate is liable to no alteration from air; it may be kept for a long time without suffering any change.

It dissolves very readily in water. Six parts of cold water are sufficient to dissolve one of this salt. A considerable cold is produced as the solution takes place, and that cold is still keener when the salt is mixed with ice. This artificial cold is happily applied to produce several phenomena which could not otherwise take place, such as the congelation of water on certain occasions, the crystallization of certain salts, the fixation and preservation of certain liquids, naturally very subject to evaporation, &c.

Boiling water dissolves a quantity of ammoniac, nearly equal to itself in weight. This salt may be crystallized by cooling; but, like other salts, it gives the most regular crystals by slow or spontaneous evaporation. A strong solution of this salt when inclosed in a flask, often deposits at the end of a few days bundles of crystals, consisting of an horizontal thread, with others united to it in a perpendicular direction; and these again supporting others; so that the whole together displays a very natural imitation of vegetation. I

have several times observed this phænomenon in my own laboratory *.

Aluminous earth does not decompose ammoniacal muriate. Magnesia decomposes it, but with great difficulty, and only in part, as Bergman has observed. If a mixture of magnesia and a solution of ammoniacal muriate be put into a phial, at the end of a few hours, as the celebrated chemist of Upsal has observed, there is disengaged a quantity of ammoniac vapours; but this phænomenon soon ceases, and but a very little of the salt is decomposed.

Both lime and barytes separate ammoniac from the muriatic acid even cold. The ammoniac gas is instantly volatilized, if this salt be but triturated with quick-lime; and its smell makes a lively impression on the nerves. When this experiment is performed in close vessels, the ammoniac may be collected in water, either in a gaseous state or dissolved. As no author has given a particular explanation of the method of performing this operation, though modern improvements have rendered it both accurate and certain, we think ourselves obliged to give a full description of it in this place.

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* Every chemist knows of what advantage it is to examine from time to time products preserved in a laboratory, more especially solutions of salts. When chance offers any curious facts to our observation, we ought always to note them down, that we may not lose what may be afterwards found of high importance. Thus have I many times seen crystals formed which I could not obtain by evaporation. It happens too, that when phials are moved or uncorked, crystals are soon after deposited; for motion and the contact of the air are highly favourable to the production of these. This note, though unnecessary to those who have been long employed in chemical pursuits, may be of use to those who are just beginning to engage in such studies.

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A mixture of strong quicklime and very dry ammoniacal muriate heated in a retort, with its extremity immersed into a bell-glass full of mercury, affords a large quantity of alkaline gas or ammoniac. It is now known why scarce any product is obtained, and the operator is exposed to danger from the breaking of the vessels, when such a mixture is distilled in balloons without a pneumato-chemical apparatus. These circumstances arise from the rarefaction of the mixture, and the quantity of the ammoniac gas disengaged. M. Baumé, having himself experienced part of those inconveniences, gives it as his advice to put water into the retort. This fluid absorbs and carries off part of the gas; but as the gas is much more volatile than water, a great part of it is always lost. Chemists who are now acquainted with the strong affinity between ammoniac gas and water, and with the amazing volatility of the gas, employ Mr Woulfe's apparatus very successfully in performing this operation. This ingenious process consists in fitting to a balloon with two necks an empty bottle, and joining to it two or four collateral bottles connected by syphons. Quicklime and dry powdered ammoniacal muriate are put into a stone retort, which is meant to be luted to the balloon: a moderate heat is then cautiously applied till the bottom become red-hot, and even begin to vitrify. The ammoniac gas being disengaged by the lime, passes into the balloon and the bottles, unites with the water with heat, and forms in the first bottles what is called *volatile spirit of alkali*, in the strongest and most caustic state in which it can possibly be obtained. By this means none of the ammoniac is lost; and besides the product is very white and pure, and the operator is in no danger from the vapour, or the bursting of the vessels.

fels. Bucquet and I likewise found by a great many experiments, that one part and an half of lime, instead of three parts which are usually employed, are sufficient to decompose one part of ammoniacal muriate. Lime slaked by exposure to the air decomposes this salt as well as quicklime. The residue after this operation is calcareous muriate, which shall be hereafter examined. This process proves lime to have a greater affinity than ammoniac with the muriatic acid.

The two fixed alkalis, as well as lime, decompose ammoniacal muriate, and disengage the ammoniac in a pure gaseous form. These, as well as lime, may be made use of to separate spirit of alkali. But they are not usually applied to that purpose in the laboratories; because the use of them on that occasion would render the process much more expensive, without affording any new advantage.

The sulphuric and the nitric acids separate the muriatic acid from this salt, and enter themselves into combination with the ammoniac, with which they have a stronger affinity. The residues are ammoniacal sulphate and nitrate.

Scarce any of the alkaline neutral salts acts upon ammoniacal muriate; none but those which are formed by the combination of the carbonic acid with the two fixed alkalis decompose it. A double decomposition and combination takes place on such occasions. In fact, while the muriatic acid unites with the fixed alkalis to form muriate of potash or of soda, the carbonic acid separated from the alkalis meeting with the ammoniac, at the same time left in a separate state, forms ammoniacal carbonate, which is sublimated and formed into crystals that are found scattered all over the inner sides of the balloon. In performing this operation, one part of potash or soda, which must be very dry,

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dry, is mixed with another of sublimated ammoniacal muriate in powder. This mixture is put into a stone retort, to which a large balloon, or rather a glass cucurbite, must be fitted; and fire is now gradually applied till the bottom of the retort be made red-hot. A white salt in fine crystals passes by sublimation into the cucurbite, (which is ammoniacal carbonate). A little water passes at the same time, and the residue is muriate of potash, or of soda, according as the one or the other of those fixed alkalis was employed. By this means we obtain a very considerable quantity of the salt, equal to no less than two-thirds of the ammoniacal muriate which entered into the mixture. This phenomenon induced Duhamel to think that a little fixed alkali escaped along with the volatile. It is easy to understand, since modern experiments have thrown light on this theory, that what gives on this occasion so considerable a quantity of the sublimated salt is the union of the carbonic acid separated from the fixed alkali, with the ammoniac. Till of late, however, this concrete volatile alkali was always thought to be the purest; and to it were ascribed the properties of crystallizing and effervescing with alkalis; while that obtained by lime, which is pure volatile alkali, was thought to be a salt that had been altered, and in part decomposed. From this we see what new light the discoveries of Dr Black have thrown on the nature of saline matters; and we cannot help saying that they have rendered chemistry quite a new science.

Ammoniacal muriate is applied to various purposes. In medicine it is administered internally as a discutient in obstructions and intermittent fevers, &c. in doses of a few grains. Externally applied, it is a powerful antiseptic in gangrenous cases, &c. &c.

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It is used in many of the arts, more especially in dyeing and in metallurgy, when different metals are to be foldered together. Braziers use it to clear the surface of copper which they are going to cover with tin.

Species IV. *Ammoniacal Borate.*

AMMONIACAL borate, or the saturated combination of the boracic acid with ammoniac, has not been yet examined by any chemist. I have made the following observations on some of its properties.

I dissolved a quantity of very pure boracic acid in ammoniac, or caustic volatile alkali, till the substances appeared to be mutually and completely saturated: this solution I diluted in a little water, and then evaporated in a sand-bath about one half of this liquor. When cooled, it afforded a layer of crystals joined together, and exhibiting on their surface polyhædral pyramids. This salt has a poignant urinous taste; it turns syrup of violets green, gradually loses its crystalline form, and becomes brown by the contact of the air. It dissolves readily enough in water. Lime disengages the ammoniac.

These are chief properties which I observed on a first examination of it: but I have not yet made enough of experiments upon it to be fully acquainted with its nature.

Ammoniacal borate is not applied to any use.

Species

Species V. *Ammoniacal Fluide.*

THIS salt, like the preceding, is scarce sufficiently known to be distinguished by its peculiar properties from other ammoniacal salts.

M. Boullanger agrees with Scheele, that the fluoric acid when combined with ammoniac does not crystallize, but forms a jelly; which exhales vapours like those of the muriatic acid, upon the addition of a portion of the sulphuric. Neither of those chemists has examined the other properties of this salt; but they had learned enough to enable them to distinguish between the fluoric and the muriatic acids.

Species VI. *Ammoniacal Carbonate.*

WE give the name of *ammoniacal carbonate* to a kind of neutral salt, which was formerly called *concrete volatile alkali*, but is actually a neutral saline combination of the carbonic acid with ammoniac.

It does not exist in nature in a pure insulated state; but it may be obtained from almost any animal substance by the action of fire. It is likewise formed by the direct union of ammoniac with the carbonic acid, 1. By shaking that alkali in the upper part of a vessel containing fermenting liquor. 2. By causing the carbonic acid to pass into volatile spirit of alkali. 3. By pouring this acid into a vessel, the sides of which are wet with ammoniac diluted in water. 4. By a direct combination of the carbonic acid gas with ammoniac gas above mercury; the two gaseous substances instantly unite, a strong heat is excited, and a concrete

salt is formed on the sides of the glass in which the mixture is made up. In all of these cases ammoniacal carbonate is instantly formed in crystals. The same salt is likewise obtained by decomposing ammoniacal muriate with carbonic neutral salts having a base of potash or soda.

Ammoniacal muriate may be caused to assume a regular form. Its crystals appear to be prisms with a number of sides. Bergman calls them *octohædrons* with four of their angles truncated. M. Romé de Lille mentions his having seen this salt in groupes of small tetrahædral prisms, terminating at the upper extremity in a dihædral summit.

Its taste is urinous, but much weaker than that of pure caustic ammoniac; its smell, though not unlike that of ammoniac, is also much fainter; it communicates a green colour to syrup of violets. It may here be proper to observe with respect to the last-mentioned property, that the carbonic is not the only acid which does not absolutely destroy the characters of such alkalis as it is combined with; and that there is no reason on this account to refuse the name of neutral salts to alkalis saturated with this weak acid; for the boracic acid is of the same character, as to its effects on alkalis; and no chemist has ever intimated a doubt whether borax be a neutral salt.

Ammoniacal carbonate is very volatile, the least heat being sufficient to sublimate it entirely. If regularly crystallized, it begins to liquefy when heated, with the help of the water to which it owes its crystalline form. But it is volatilized nearly at the same time; which renders it almost impossible to obtain this salt very dry and regularly crystallized.

It dissolves very readily in water, producing cold at
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the instant of its solution, like all other crystallizing neutral salts. This property alone, plainly distinguishing it from pure ammoniac, which on the contrary produces a considerable heat when it combines with water, might be sufficient to class ammoniacal carbonate among the neutral salts. Two parts of cold water dissolve rather more than one of this salt; warm water dissolves more than a quantity equal to itself in weight. But, as the heat of boiling water dissipates it, we cannot adopt this method of crystallizing it, without running the risk of losing a considerable part.

It becomes somewhat moist when exposed to the air, and is the more liable to this when not entirely saturated with the carbonic acid.

Neither siliceous nor aluminous earth acts upon it any more than on the other neutral ammoniacal salts. Magnesia decomposes it but very feebly. Lime has a stronger affinity than ammoniac with the acid, and decomposes this as well as other neutral salts. Lime-water poured upon a solution of the ammoniacal carbonate, immediately gives a precipitate, and a strong smell of caustic ammoniac is at the same time diffused around. The lime seizing the carbonic acid, forms with it chalk or calcareous carbonate, which is precipitated, and the ammoniac is separated. Quicklime, triturated with ammoniacal carbonate, instantly disengages the ammoniac in a gaseous form. The caustic ammoniac may be obtained from this mixture by putting it into a retort accommodated with Woulfe's apparatus, just as the volatile alkali is obtained from ammoniacal muriate distilled in the same manner. This decomposition proves lime to have a greater affinity than ammoniac

moniac with the carbonic acid, as well as with the other acids.

The fixed alkalis decompose ammoniacal carbonate as well as lime, by separating the pure ammoniac, and combining with its acid.

Lastly, the sulphuric, the nitric, the muriatic, and the fluoric acids, have more affinity with ammoniac than the carbonic acid. When any of these acids is poured on ammoniacal carbonate, it produces a lively effervescence by disengaging the carbonic acid. If this decomposition be performed in a long strait vessel, certain evidence may be obtained of the presence of the carbonic acid, by immersing into it a taper, which is instantly extinguished,—tincture of turnsol, which assumes a red colour,—or lime-water, which is precipitated. These decompositions of ammoniacal carbonate by lime and the fixed alkalis,—which by seizing the acid, separate the ammoniac, and by the acids,—which by uniting with the alkali, disengage the carbonic acid, shew clearly the peculiar nature of ammoniacal carbonate. Bergman found by accurate experiments, that a quintal of this salt in crystals contains forty-five parts of carbonic acid, forty of ammoniac, and twelve of water. As this salt contains more of the acid than carbonate of soda, and carbonate of soda more than carbonate of potash, that ingenious chemist concludes, that the weaker the alkaline base, so much the more acid is requisite to saturate it. The boracic acid does not decompose ammoniacal carbonate cold; but when a hot solution of the boracic acid is poured on this salt, a very discernible effervescence is produced. The carbonic acid then disengaged may be collected by the usual means; and what is found at the bottom of the vessel

is genuine ammoniacal borate. This experiment, which I have often repeated, confirms Bergman's observation, that heat modifies or changes the laws of elective attraction.

Ammoniacal carbonate does not act on perfect neutral salts. But we will hereafter see that it decomposes calcareous neutral salts by the way of double affinity, which pure caustic ammoniac does not. This fine discovery of Black's explains the reason of what the chemists had long asserted, that ammoniac has a greater affinity than calcareous earth with the acids.

Ammoniacal carbonate is used in medicine as a sudorific, an anti-histeric, &c. It is mixed with some aromatic matters. It has been considered almost as a specific in the case of a viper's bite; but the Abbé Fontana with good reason opposes that notion. Many have advised the use of ammoniacal carbonate or concrete volatile alkali in venereal complaints; but experience has not yet determined certainly how far it is useful in such cases. All that we know concerning the application of this salt in the medical art is, that it is purgative, incisive, diuretic, diaphoretic, and discutient; and that it acts powerfully in all distempers arising from the thickening of the lymph, such as venereal misfortunes, coagulations of milk, scrophulous swellings, &c.

It is given in doses of a few grains in certain drinks, or in pills mixed with opium.

C H A P. VII.

Genus III. *Calcareous Neutral Salts:*

Species I. *Sulphate of Lime, Selenite, or Gypsum.*

THE combination of the sulphuric acid with lime is properly *calcareous sulphate*, but is commonly known by the name of *selenite*, *plaster*, or *gypsum*. This salt abounds in nature. It is often found in vast banks or layers; as for instance at Montmartre near Paris. At that place whole mountains are filled with strata of selenite or plaster, covered over with a kind of argillaceous marl, which is almost always found with it.

As this salt has but very little taste, and is scarce soluble, naturalists have long considered it as a stony substance; and they have distinguished it into many varieties, according to its various degrees of purity, and the various forms under which it appears. We shall mention the chief of those varieties.

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The Principal Varieties of Calcareous Sulphate.

1. Calcareous sulphate, or selenite in rhomboidal plates.

It is transparent like ice: the pieces which are shown in cabinets of natural history are irregular; but they always split into rhomboidal plates. Such are those at St Germans and Lagny, &c.

2. Cuneiform calcareous sulphate or selenite; or in the form of arrow-heads.

It consists of two scalene triangles joined in the middle, each of which, as M. de la Hire has observed, consists of triangular plates. This stone is called *lapis specularis*, or talc of Montmartre.

3. Calcareous sulphate or selenite in decahædral rhomboids.

Of this kind is that found in the quarries of Passy.

4. Calcareous sulphate or selenite in decahædral prisms.

This consists of hexahædral prisms, terminating in dihædral pyramids, or in a concave angle. It is found in Switzerland, &c.

5. Calcareous sulphate or selenite in cock's combs, from Montmartre.

These are collections of small lenticular crystals, disposed obliquely one beside another. They are formed by the union of the arrow-heads, of which we have spoken under the second variety.

6. Silky or striated calcareous sulphate or selenite, silky gypsum of China.

It is found in Franche-Comté, Angoumois, &c. It is in the form of very fine prisms, bundled together, usually bright and glossy like satin. It is very difficult

to distinguish in this the rhomboidal plates, which are observed in all the other varieties.

7. Calcareous sulphate, common gypsum, or plaster-stone.

This substance is of a greyish white colour, spangled with small sparkling crystals, which may be easily taken out with a knife. It is found in strata; and most of the mountains about Paris consist of it. We will afterwards understand that this is not pure selenite, and does not make good plaster till after being mixed with another earthy salt.

8. Calcareous sulphate in the form of alabaster, or gypseous alabaster.

This is a sort of plaster-stone, harder, and apparently of an earlier formation than the last described; from which it differs only as being half transparent, and consisting of small layers, as is observed of stalactites. There is a great deal of it found at Langry near Paris. This is one of the whitest kinds, and is sometimes veined or spotted with yellow, grey, violet, or black spots.

9. Calcareous sulphate, selenite, common gypsum, or gypseous alabaster, coloured, veined, spotted, clouded, and punctuated.

This mixture of colours shows the selenite to be contaminated with some extraneous colouring matter. The colours of this earthy salt are almost always occasioned by iron in various states.

Calcareous sulphate is likewise found dissolved in water, as for instance in the wells of Paris; but never pure, and always combined with some other earthy salt, having lime or magnesia for its base.

We have already mentioned that calcareous sulphate was long taken by naturalists for a stony substance. They thought

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thought it could not be a salt, as being apparently insipid and insoluble: but it actually communicates a peculiar sapidity to water,—which is very sensible in the stomach. Crude water, or water impregnated with selenite, affects the stomach with a certain cold and heaviness. As to its solubility; the form, size, transparency, quantity, and strata, of the crystals of calcareous sulphate, in many places, and particularly all around Paris, shew plainly that it must have been once dissolved in water, and afterwards deposited by that fluid.

Calcareous sulphate, when exposed to the action of fire, loses the water of its crystals, and when suddenly exposed to a strong heat decrepitates: it then assumes a rough white appearance, and becomes very friable. Under this form it is called *fine plaster*. When mixed with water, it admits of being wrought into a paste, of which very white and beautiful statues are cast in moulds. But as this plaster soon dries, retaining but very little water, the statues are apt to break under the slightest blow. If the fire be continued after calcareous sulphate is reduced to a white powder, it melts at length into a kind of glass. But to produce this effect, the most intense heat is requisite, such as that of porcelain furnaces, or the focus of a burning-glass. Messrs d'Arcet and Macquer accomplished the melting of calcareous sulphate. M. Macquer has observed, that when cuneiform selenite is exposed to the focus of a burning-glass, so as that the light may fall on its polished surfaces, it only becomes white; but when its edges are exposed, it instantly melts and boils. Bergman's blow-pipe, or a stream of vital air poured on a burning coal, likewise melts it.

Calcareous sulphate becomes phosphoric when laid

on hot iron; and this property is common to all calcareous salts. We have seen that lime likewise displays it, when slaked.

Calcareous sulphate suffers no very observable alteration from the action of air; yet when exposed to the open atmosphere, the sparkling and polished plates of this earthy neutral salt lose their lustre, assume the variegated colours of the rainbow, split into laminæ, and at length waste away. But these phænomena are owing to the joint influence of heat, water, and air.

Calcareous sulphate dissolves in water, though slowly and insensibly. According to the chemists of Dijon, about 500 parts of water are requisite to dissolve one of this earthy salt. Warm water dissolves it not in a greater proportion. We cannot obtain by evaporating this salt crystals resembling those of nature; on such occasions, as the boiling liquor is gradually evaporated, small scales or needles are precipitated. The scales or plates obtained by evaporating a solution of calcareous sulphate are usually sparkling, and when narrowly examined appear to be formed of very fine needles joined longitudinally.

Barytes, having a greater affinity than lime with the sulphuric acid, decomposes calcareous sulphate. If a solution of barytes be poured into water containing a portion of this salt, striæ of barytic sulphate are instantaneously formed.

The fixed alkalis likewise decompose this neutral salt. When caustic fixed alkali is poured into a solution of calcareous sulphate, a white precipitate is produced in mucilaginous flakes, which are soon accumulated at the bottom of the vessels, and easily distinguished to be quicklime by various means; and among others, because much water is requisite to dissolve them.

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If the incumbent liquor be evaporated, the residue after evaporation is sulphate of potash or of soda, according as vegetable or mineral alkali was made use of on the occasion.

As ammoniac has not so strong an affinity with any of the acids as lime, it is unable to decompose calcareous sulphate when that salt is very pure, and the ammoniac made use of very caustic: but if water in which calcareous sulphate is dissolved, contain some other salt with a base of magnesia or aluminous earth, such as, for instance, the wells at Paris, ammoniac effects a precipitation of it. To succeed in this experiment, we must dissolve calcareous spar in pure sulphuric acid, and dilute that sulphate of lime in distilled water. Caustic ammoniac poured into such a solution, or, what is still better, ammoniac gas caused to pass through it, produces no precipitate.

Carbonate of potash and calcareous sulphate mutually decompose each other. When these substances are mixed, a double decomposition and combination take place. The sulphuric acid forsakes the lime, in order to form sulphate of potash by uniting with the fixed alkali; and the carbonic acid being separated from the potash combines with the lime to form calcareous carbonate, which is well known under the name of *chalk*.

Carbonate of soda likewise decomposes calcareous sulphate, and is decomposed in its turn. Sulphate of soda is formed on this occasion by the combination of the sulphuric acid with mineral alkali; and calcareous carbonate or chalk by the combination of lime with the carbonic acid.

Ammoniacal carbonate decomposes calcareous sulphate by a double affinity. The sulphuric acid tends

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to unite with the ammoniac; while the lime is attracted by the carbonic acid, with which it has a great affinity, and by combining with it forms a precipitate of chalk.

This decomposition is very discernible; and Dr Black's discoveries have given a very satisfactory explanation of the cause by which it is produced. And if a mixture of the solution of calcareous sulphate and caustic ammoniac be for some time exposed to the air, though it were at first perfectly transparent, its surface soon appears clouded, in consequence of the carbonic acid being precipitated from the atmosphere, and giving rise to a double affinity. The same phænomenon may be produced by causing a few bubbles of this gaseous acid to pass into the liquid. As concrete volatile alkali, or ammoniacal carbonate, was formerly thought to be pure volatile alkali,—Geoffroy, believing that this alkali actually gave a precipitate from calcareous sulphate, concluded it to have a greater affinity than lime with the sulphuric acid.

Many combustible matters, with the help of heat, decompose calcareous sulphate. Coal from vegetable substances, having a greater affinity than sulphur with the oxygenous principle, robs the sulphuric acid of that part of its composition. The carbonic acid is disengaged on this occasion; and the sulphur separated from the sulphuric acid uniting with the lime, forms what is called *calcareous hepar* or *liver of lime*, to which we will, in future, give the name of *sulphure of lime*.

The varieties of crystallized calcareous sulphate are carefully preserved in natural history collections. When calcined and wrought in water, it is used in casting statues, &c. Various handsome pieces of ornamental furniture are formed of gypseous alabaster, cut and polished,

polished. Lagny affords fine blocks for that purpose.

Plaster-stone is one of the most useful matters in nature. It is a mixture of calcareous sulphate and calcareous carbonate or chalk. When exposed to the action of fire, the calcareous sulphate loses the water of its crystallization and the chalk its acid. Burnt plaster is therefore a mixture of quicklime and calcareous sulphate without water. If water be poured on this substance, the lime eagerly absorbs it, giving out heat. The fetid odour which is felt when burning plaster is extinguished, is occasioned by the sulphur produced by the decomposition of the sulphuric acid by the animal or vegetable carbonaceous matters which are always found to exist in plaster-stone. The sulphur then separated forms a kind of *sulphure*, or liver of sulphur, from which the disagreeable smell proceeds. When the lime has absorbed enough of water to make it paste, it includes a portion of calcareous sulphate, which, attracting part of the water, crystallizes in the midst of the paste. The lime becoming gradually dry, acquires a solid consistency, with the help of the crystals of calcareous sulphate, and forms a kind of mortar which is called *plaster*. From what has been here said, it may be understood why plaster must be burnt to a certain degree and no farther. When not sufficiently burnt, it does not unite with the water, because the lime is not quick enough: when too much burnt, the lime unites with the calcareous sulphate to form an indifferent species of vitreous frit which cannot combine with the water; this is called *burnt plaster*. It may be likewise understood, that the reason why plaster loses its qualities when exposed to the air, is the gradual flaking of the lime. When calcined anew, it regains

its original properties. Lastly, it is easy to see why plaster is preserved unchanged in dry hot places, and why in damp situations it wastes gradually away in scales or plates. In the last of these cases, calcareous sulphate, which is soluble in water, gradually loses its consistency and crystalline form. It is this solubility that distinguishes plaster from mortar, the sandy base of which is proof against the attacks of water. Plaster is on this account unfit for use in places containing water, such as reservoirs, and other works of a similar kind; nor does it retain its hardness in low or subterraneous places.

Species II. *Calcareous Nitrate.*

CALCAREOUS nitrate, or the salt resulting from the combination of the nitric acid with lime, is far from being so copious in nature as calcareous sulphate or selenite. It is found only in such places as afford alkaline nitre. It is formed on the sides of walls, in places inhabited by animals; it is found likewise in putrefying animal matters, and in some mineral waters. But as it dissolves very readily, and even deliquesces, it is dissolved as fast as formed; and from this circumstance, it exists in large quantities in mother-water of saltpetre.

When regularly crystallized by a process which we are hereafter to describe, it exhibits solid prisms of six faces, pretty much like nitrate of potash, and terminating in dihedral pyramids. It is but seldom obtained in so regular a shape, but usually in small needles, adhering together, and of an indeterminate form.

The taste of this salt is bitter and disagreeable, very
different

different from that of calcareous sulphate. It even tastes somewhat fresh, like nitrate of potash.

It easily liquefies in the fire, and becomes solid by cooling. If taken into a dark place, after being thus heated, it becomes luminous; and in this state it is called Baldwin's phosphorus, *Balduinus*. It exhibits the same phænomenon when put on a red iron. When thrown on burning coals, it liquefies and detonizes slowly, in proportion as it becomes dry. Calcareous nitrate, when long heated, loses its acid, which is decomposed by the action of heat. When this operation is performed in a retort, the extremity of which enters a bell-glass full of water, a product of vital air is obtained, and towards the end of the operation azotic gas. The residue is lime, in combination with a certain quantity of nitrous acid, if only a moderate fire has been employed, and that for a short time. But strong quicklime may be obtained by this process, if extreme violence of fire be applied and continued long enough to effect a total decomposition of the nitrous acid. This decomposition of the acid is precisely the same with that which is effected by the distillation of nitre of potash, as we have shown in the history of that neutral salt.

Calcareous nitrate attracts very rapidly the moisture of the atmosphere. And it must therefore be kept in very close vessels when we wish to preserve it in crystals; it even wastes away very quickly if the mouths of the vessels be too often unstopped.

This salt dissolves very readily in water. No more than two parts of that fluid, even cold, are requisite to dissolve one of calcareous nitrate: boiling water dissolves a quantity more than equal to itself in weight. To obtain this salt in crystals, we must evaporate the solution, and when it acquires nearly the consistency
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of syrup set it aside in a cool place: it then forms very long prismatic crystals, which are usually bundled together in needles diverging from a common centre. When a solution of calcareous nitrate, not just so much evaporated as the last, is exposed to a dry warm temperature, it at length forms more regular prisms, like those which were described at the beginning of this article.

Sand and clay decompose calcareous nitrate, and separate the acid.

Barytes, according to Bergman, decomposes this salt, as well as calcareous sulphate: magnesia produces no sensible alteration on it. M. de Morveau has observed, that lime-water poured on a solution of calcareous nitrate produces a precipitate. He ascribes this effect to the phlogiston of quicklime, which, in his opinion, has a greater affinity with the nitrous acid than with lime. Unluckily that chemist did not examine the nature of the precipitate, otherwise he must certainly have obtained some farther knowledge concerning the phenomena of this curious experiment, M. Baumé had before observed, that lime water precipitates a solution of calcareous spar in nitrous acid, but ascribed that phenomenon to a small portion of argillaceous earth contained in the spar. This effect must depend either on a little magnesia, or on the avidity with which calcareous nitre absorbs the water from the lime.

The fixed alkalis attract the nitric acid from calcareous nitre, and by that means precipitate the lime. Pure ammoniac does not decompose this salt any more than sulphate of lime and the other calcareous salts in general.

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salt with effervescence. The acid thus disengaged may be obtained in a receiver in the same way as common nitre. The sulphuric acid, when poured into a solution of calcareous nitrate, gives immediately a precipitate of sulphate of lime, leaving the nitric acid free and separate in the liquor. We are as yet ignorant in what manner the other acids act upon this salt.

Calcareous nitrate decomposes sulphuric alkaline neutral salts. The result of this decomposition is sulphate of lime and nitre of potash or soda. Ammoniacal sulphate, too, when mixed with a solution of calcareous nitrate, gives ammoniacal nitrate and sulphate of lime. The last of these salts being scarce soluble, is precipitated at the instant of the mixture; which establishes the certainty of this double decomposition beyond a doubt.

Carbonate of potash likewise dissolves, and is in its turn dissolved by, calcareous nitrate. This double decomposition gives nitrate of potash, which remains dissolved in the liquor; and chalk or calcareous carbonate, which is precipitated.

Carbonate of soda acts in the same manner on calcareous nitrate, giving nitrate of soda, which remains dissolved in the water,—and calcareous carbonate or chalk, which is precipitated.

Ammoniacal carbonate likewise decomposes this salt by double affinity. Ammoniacal nitrate and carbonate of lime are formed on this occasion.

Sulphate of lime produces no alteration on calcareous nitrate; but when these two salts are found dissolved in the same water, as the first is scarce soluble, and the second dissolves very readily, they may be separated by crystallization. The sulphate of lime is precipitated

precipitated at the first, and the calcareous nitrate does not crystallize till the liquor be greatly condensed by cooling.

Calcareous nitrate is applied to no use. It might be used in medicine as a very active discutient; and some medical chemists relate their having used it with success, though they were not much acquainted with its properties.

Species III. *Calcareous Muriate.*

CALCAREOUS muriate, the salt formed by the combination of the muriatic acid with lime, which was formerly known by the improper name of *fixed sal ammoniac*, *oil of lime*, &c. abounds wherever muriate of soda is found, more especially in sea-water, to which it communicates its acrid bitter taste; which was formerly ascribed to bitumen, supposed to be contained in the water. But it is never pure in that fluid, being always mixed with muriate of magnesia. In order to procure calcareous muriate very pure, we must make a direct combination of the muriatic acid with lime to the point of saturation.

This salt, when dry and solid, appears in prisms with four striated faces, terminating in very sharp-pointed pyramids. It has a salt and very disagreeable bitter taste. When exposed to the action of a moderate fire, it liquefies by means of the water of its crystals, and becomes fixed by cooling. When exposed to a stronger fire, it suffers scarce any alteration. M. Baumé has observed, that on this occasion it does not lose its acid. When put on a red shovel, it becomes
luminous;

luminous; on which account it is called *Homborg's phosphorus*.

That portion of calcareous muriate which remains in the retort after the decomposition of ammoniacal muriate by lime, is called *fixed sal ammoniac*. It melts into a kind of frit, of a light slate grey, without giving out any muriatic acid, even though exposed to a degree of heat sufficient to vitrify the surface of the retort. This frit gives fire with steel; and when rubbed in the dark with a piece of the same metal, gives out phosphoric sparks.

It is to be observed, that this saline residue usually contains more lime than what is requisite for the saturation of the muriatic acid; because more than the necessary quantity of lime is employed to decompose ammoniacal muriate. This residue, no doubt, owes its property of affording an hard vitreous frit to its containing an extraordinary quantity of lime; for otherwise the frit would surely at length acquire moisture and suffer alteration when exposed to the air. Calcareous muriate, when it contains no extraordinary portion of lime, never assumes that degree of hardness which distinguishes this residue, nor displays any phosphoric powers.

Pure calcareous muriate, when exposed to the air, rapidly attracts moisture, and wastes entirely away by deliquium. It must be kept in a well stopped vessel when we wish to preserve it in its crystalline form.

This salt dissolves very readily in water,—about a part and an half of the fluid being sufficient to dissolve one part of calcareous muriate. Warm water dissolves a portion more than equal to itself in weight. If this solution be evaporated till it acquire the consistency of syrup, and then left to cool slowly, it crystallizes into

to tetrahædral prisms, several inches in length, and placed in the disposition of radii, diverging from a common centre. We may observe, that this is almost invariably the form of all calcareous salts. When the liquor is too much evaporated, or too hastily cooled, it becomes a shapeless mass set with sharp points on the surface.

A solution of calcareous muriate evaporated to 45 degrees of M. Baumé's areometer, and then exposed to cold in a bottle, deposits very regular, and often very large, prismatic crystals. Sometimes when this solution is shaken before being crystallized, it is suddenly formed into a very solid mass; at which instant it gives out a great deal of heat.

Barytes, according to Bergman's experiments, having a greater affinity than lime with the muriatic acid, decomposes calcareous muriate. Lime and magnesia produce no alteration on this salt.

The fixed alkalis precipitate the lime. If the two liquors be concentrated, the lime, absorbing the small portion of water which they contain, forms almost instantaneously a jelly which soon becomes quite solid. This experiment is called a *chemical miracle*; because it exhibits two fluids passing suddenly into a solid state. But it does not succeed well except with a solution of carbonate of potash and soda; for the pure caustic alkalis precipitate the lime in too divided a state.

Caustic ammoniac does not decompose calcareous muriate; for it has not so great an affinity as lime with the muriatic acid: a fact which proves that ammoniacal muriate may be completely decomposed by this salino-terreous substance.

The sulphuric and the nitric acids disengage the muriatic acid from this salt with effervescence; and
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with a distillatory apparatus, the acid might be obtained from this salt in the same manner as from muriate of soda. The distillation of this earthy salt with the nitric acid gives the nitro-muriatic acid, or *aqua regia*, because of the volatility of the two acids.

Calcareous muriate decomposes sulphate of potash and soda. The reader may obtain the fullest conviction of the truth of this fact by mixing solutions of these salts. A precipitate is immediately produced, which may be distinguished to be sulphate of lime. The incumbent liquor contains muriate of soda or potash, which may be obtained by evaporation; nay, even the taste of the liquid is a proof of its existence.

Carbonate of potash or soda likewise decomposes calcareous muriate. Two decompositions and two combinations take place on such occasions. The muriatic acid contained in the latter salt, deserting its base, combines with the potash or soda to form muriate of potash or soda, which remains dissolved in the liquor; and the carbonic acid likewise forsaking the fixed alkalis and combining with the lime, forms a precipitate of chalk or calcareous carbonate. If carbonate of potash or of soda be dissolved in a very small quantity of water, and the solution of calcareous muriate be at the same time concentrated, the mixture becomes thick and gelatinous. It then assumes greater consistency, and hardens into a kind of factitious stone, if the two substances be justly proportioned in the composition. The first chemists who observed this phenomenon called it *a chemical miracle*.

Ammoniacal carbonate decomposes calcareous muriate by a double affinity, in the same manner as calcareous sulphate and nitrate. The ammoniac com-

bins with the muriatic acid, forming ammoniacal muriate, which remains dissolved in the liquor; while the carbonic acid combining with the lime, forms calcareous carbonate, which is precipitated.

If calcareous muriate and calcareous nitrate be dissolved together in water, it becomes very difficult to separate them, because they are both crystallized by the same laws. But calcareous muriate and sulphate may be easily obtained separate; for the last crystallizing only by evaporation, leaves the calcareous muriate pure, and it then crystallizes by cooling. This observation is of some importance; for these two salts are often found in solution in the same mineral water.

Calcareous muriate has not yet been applied to many purposes. It exists in a large proportion in the gabel salt, recommended in scrophulous cases as a purging discutient; and I have already observed that gabel salt is indebted to it for part of its properties. I likewise observed that the strong taste of calcareous muriate, and its tendency to solution, give us reason to expect very happy effects from it in all distempers in which an alteration of the humours is requisite. It is greatly to be wished that physicians were acquainted with its properties, and would prescribe it in many of those cases in which the usual discutients are found not to act with sufficient efficacy, especially in instances when mercurial preparations cannot be safely administered. I have already given the result of all my experience concerning the nature of this discutient salt in a memoir inserted among those of the Royal Society of Medicine for the years 1782 and 1783.

Species

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Species IV. *Calcareous Borate.*

THIS name may be given to the combination of the sedative or boracic acid with lime. This salt has never been examined, though it be certain that the boracic acid is capable of combining with lime, as lime decomposes borax of soda. The chemists of the academy of Dijon have observed, that the concrete boracic acid, when treated in fire, with slaked lime, affords a matter whose parts adhere very feebly together, and take no hold on the crucible. If this matter be cast into water, it displays none of the characteristics of lime; and this proves that a combination must actually have taken place. M. Baumé mentions his having saturated lime-water with sedative salt: the liquor when evaporated in the air afforded no crystals, but yellowish pellicles, having a faint taste of the boracic acid. Lastly, the academicians of Dijon digested on a sand-bath a saturated solution of this acid with slaked lime. This solution, when filtered, gave a copious white precipitate on the addition of fixed alkali. These several experiments show nothing more than the possibility of dissolving lime by the boracic acid, and give us no information concerning the properties of the neutral salt which results from the combination then effected.

Species V. *Fluor Spar, or Calcareous Fluete.*

THIS salt is a combination of the fluoric acid with lime. It abounds through nature. It is found more especially

especially in the neighbourhood of mines, the existence of which it always indicates. Hitherto it has been considered as a stone, on account of its insipidity, hardness, and insolubility. It is called *spar*, as being of a spathose form and fracture; *fluor* or *fusible*, because it melts very readily, and is even employed advantageously as a flux in the working of mineral ores; *vitreous*, because it has the appearance of glass, and may even be formed by fusion into a very fine species of glass; *cubic*, because it appears always under a cubic form; and *phosphoric*, because when heated and taken into a dark place it has a luminous appearance. Before Scheele's discovery of it, vitreous spar, though sufficiently distinguished by the miners from all other mineral matters, in consequence of its fusibility, had been always confounded by naturalists with gypseous substances, calcareous and ponderous spars, which have been also called *fusible*. The celebrated Margraaf, however, had established a distinction between this salt and ponderous spar; appropriating to the former the name of *vitreous fusible spar*, and calling the latter *phosphoric fusible spar*; and our acknowledgments are due to that chemist for the first discoveries of the properties of calcareous fluuate.

This salt appears usually under the form of very regular cubic crystals, of various colours, and of an icy and vitreous transparency. Its fracture is spathose, and exhibits cubical plates seemingly cracked at the surface. It breaks when struck against steel: it is always found in mineral ores, to which it often serves as a bed or matrix. Sometimes it is opaque, and in irregular masses. It is weightier than any of the other saline matters which we have examined. It is sometimes

times clouded, veined, spotted, and oftener green, red, rose, or violet coloured, &c.

We may take notice of ten leading varieties of this salt as it is found in nature.

Varieties.

1. Cubic calcareous fluuate, or vitreous spar, white and transparent.
2. Cubic calcareous fluuate, or vitreous spar, white and opaque.
3. Cubic calcareous fluuate, or vitreous spar, yellow; false topaz.
4. Cubic calcareous fluuate, or vitreous spar, reddish; false ruby.
5. Cubic calcareous fluuate, or vitreous spar, pale green; false aqua marine.
6. Cubic calcareous fluuate, or vitreous spar, green; false emerald.
7. Cubic calcareous fluuate, or vitreous spar, violet; false amethyst.
8. Octohædral calcareous fluuate, or vitreous spar, with truncated pyramids.

I have in my possession a crystal of this kind, which is semi-transparent and somewhat blackish.

9. Calcareous fluuate, or vitreous spar, in an irregular lamellated mass.

It is almost always of a clear green or violet colour. It forms the *gangue* of several ores, and is sometimes in rolls.

10. Calcareous fluuate, or vitreous spar, in layers of various degrees of thickness and of various colours.

Almost all of these varieties of calcareous fluat are still but one saline substance, namely a combination of the fluoric acid with lime. They are usually found, however, when carefully analysed, to contain various extraneous matters, such as siliceous earth, clay, and iron. This is the character of all natural products in general. England is very rich in calcareous fluat.

When this earthy salt is exposed to a moderate fire, it acquires a phosphoric quality in a pretty eminent degree; but if made red hot, it is entirely divested of this quality. It at the same time loses its green or violet colour, and becomes grey and friable. When suddenly exposed to a strong heat, it decrepitates almost in as lively a manner as muriate of soda. When powdered fluat of lime is thrown on an hot iron, it gives a bluish or violet light, which in an instant disappears. If exposed a second time to heat, it no longer exhibits the same phenomenon.

A strong heat melts this salt into a transparent uniform glass, which adheres to the crucibles. It melts one fourth of its weight of fine quartz, and is therefore used as a flux in smelting.

Calcareous fluat is neither alterable by air nor soluble in water. It serves as a flux for earthy and silino-terreous matters. Pure fixed alkali, whether mineral or vegetable, does not decompose it; because, according to Bergman, lime has a greater affinity than either of these salts with its acid.

The concentrated sulphuric acid disengages the fluoric acid from this salt, and is commonly employed for that purpose. One part of calcareous fluat in powder, together with three parts of sulphuric acid, are put into a glass retort. This mixture becomes gradually hot, an effervescence is produced, and the fluoric acid is disengaged in

a vaporous form. This distillation is effected without the application of external heat ; and a white substance, resembling an efflorescence, is sublimed and deposited in the receiver by the acid gas. Heat being then applied, the fluoric acid is obtained in a concentrated state, covered with a thick earthy pellicle, resembling the white efflorescence above mentioned, when it drops into water in the receiver. This acid may be obtained in a gaseous form by inserting the extremity of the retort into a bell-glass filled with mercury. This aeriform acid is transparent, and never suffers the earth combined with it to be precipitated but when it comes into contact with water. From this we understand why the liquid fluoric acid deposits stony incrustations in the bottom of the receiver : for whenever it is combined with water it becomes incapable of maintaining them in solution. We have already taken notice that this earth, being of a siliceous nature, seems to have originally belonged to the glass vessels which have been corroded by the fluoric acid, and is not produced by the combination of the acid with water, as Scheele at first imagined. At the end of the distillation, the residue is observed to be hard, of a white or reddish colour, and disposed in plates, while the retort is corroded in a very discernible manner. This did not escape Margraaf's observation : and by examining the residue, we find it to consist of calcareous sulphate mixed with siliceous, or often even with aluminous earth, and a little magnesia. The two last of these substances, as well as iron, appear to exist only accidentally in calcareous fluates. The incrustation deposited by the fluoric acid is of a siliceous nature ; for it is neither fusible nor soluble in acids, and the fixed alkalis melt it into a white durable glass. It appears from the hi-

story of this experiment, that it is impossible to distil a great quantity of this acid. I have several times tried it with a pound of calcareous fluatē, with a view to obtain a good quantity of the fluoric acid; but finding the retort always incapable of resisting so corrosive an agent, I was at length obliged to give up the hope of distilling so large a quantity.

The nitric acid decomposes calcareous fluatē; but, according to M. Boullanger, the phænomena which appear on the occasion are very different from those which we have just been describing. No incrustation is formed, as when the sulphuric acid is employed to decompose this salt. But the circumstances of this operation have not yet been examined with sufficient attention.

According to Scheele, the muriatic acid likewise separates the fluoric; but he gives no particular account of the phænomena attending this decomposition.

We are as yet ignorant of the manner in which most of the neutral salts act on calcareous fluatē. We know only that carbonate of potash or soda decomposes it by a double affinity, whereas the caustic fixed alkalis never decompose it. When one part of this salt is melted with four parts of carbonate of potash, if the mixture be thrown, when melted, into water, it gives a precipitate of carbonate of lime, which is formed by the union of the carbonic acid with the lime of the calcareous fluatē; and the liquor contains fluatē of potash, which may be obtained by evaporation in a gelatinous form. When carbonate of soda is employed, the products are carbonate of lime and fluatē of soda; and the last is obtained in crystals by evaporating the liquor.

Calcareous fluatē is not employed for any other purpose.

pose but in smelting mineral ores ; and it is an excellent flux. It might be used for the same purpose in assaying metals.

Species VI. *Carbonate of Lime or Chalk ; Calcareous matters in general.*

CALCAREOUS spar, marble, chalk, and all calcareous matters in general, are saline substances formed by the combination of the carbonic acid with lime: the proper denomination to be given them is therefore *carbonate of lime*, or *calcareous carbonate*. This substance has been ranked by naturalists among stones ; because they have not distinguished it to possess any saline properties. We shall see, however, that it has a kind of sapidity, is soluble in water, admits of decomposition, and affords when analysed a great quantity of the carbonic acid, and of the saline-terreous substance known by the name of *lime*. As calcareous spar is the last modification of a matter which exists under a vast variety of forms, and has passed through many different states, before being regularly crystallized ; it will therefore be proper to take a general view of calcareous or cretaceous substances *.

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* I am of opinion, that all those substances which are usually known in natural history by the name of *calcareous*, might, with more propriety, be denominated *cretaceous* substances. The latter term indicates the neutral saline combination formed by lime and the carbonic acid, namely, chalk, *creta* ; the former belongs properly to lime calx, which is the base of that salt. The expression *calcareous earth*, or *matter*, should be appropriated to quicklime ; *chalky*, or *cretaceous matter*, should be applied to the combination of quicklime with the acid

of

No department of natural history displays a wider field, or a fuller series of well established facts, than that of calcareous matters. Long and uniform observation, with proper opportunities of observing the gradual progress of nature in forming these bodies, has determined that the bottom of the sea is the great laboratory in which the processes necessary for their production are constantly carried on. Among the numerous tribes of animals inhabiting that immense body of water there are several classes, the numberless individuals of which appear to be destined to increase the solid mass of our globe. Such are shell-fishes, madrepores, and lithophites; the solid parts of which when examined by the chemist some time after the death of the animal, exhibit all the characteristics of calcareous matters. Calcareous mountains are formed by the successive accumulation of those marine skeletons. Tho' there be a mighty difference between these animated beings in their natural state and crystallized calcareous spar; though it be difficult to distinguish on a first view the amazing difference between the soft pulpy substance of the animal and the hard stony mass which its carcase afterwards contributes to form, and which is destined to cement and consolidate our buildings; yet it is not impossible to form an idea of the successive alterations which they must undergo before they can arrive at the state of mineral bodies. The following appear to be the gradations through which this animated organized matter must pass, before it can become

of chalk. But it is not to be expected that these two expressions which have always been synonymous, should be all at once adopted into our language, and applied to distinct substances, whatever might be the advantage arising from this use of them. A.

come transparent, crystalline, carbonate of lime, or calcareous spar.

The waters of the ocean, agitated by laws of motion, which are still unknown to us, gradually change their situation, and come to occupy a new bed. They desert one shore, and encroach upon another. M. Buffon, in his theory of the earth, gives full evidence of this fact. When the waters retire from a part of the bed which they have occupied, they leave uncovered the strata which their various motions (of which this celebrated philosopher has given so ingenious an account) have formed by the successive accumulation of the solid parts or skeletons of marine animals. These layers are almost entirely composed of shells; which losing by putrefaction the animal gluten, and with it their colours, the polish of their interior surface, and more especially their consistency, become friable and earthy, and pass into the state of fossils. Hence the production of earths and stones containing shells.

These stones are worn by the waters till they gradually lose the organic form, become more and more friable, and are at length converted into that substance known by the name of *chalk*. When a shell-stone is so hard as to be susceptible of polish, and the shells of which it consists have retained their organization, so far as still to display different colours, it is called a *lumachello*. When the marks of organization are totally destroyed, if the stone be hard and susceptible of polish, it is known by the name of *marble*. Water impregnated with chalk, deposites it on all bodies over which it flows, so as to form *incrustations*. When it filtrates through the arches of subterraneous cavities, it deposites a white opaque matter formed into conical figures, consisting of concentric layers; which resemble the

the bottoms of lamps, and are called *stalactites*. When these are accumulated in large masses, so as to fill up the caverns, and remain long under ground, they acquire a considerable degree of hardness, and obtain the name of *alabaster*. Lastly, When water impregnated with chalk, extremely fine and very much attenuated, penetrates slowly into stony cavities, and deposits that substance as it were particle by particle; these minute bodies gradually unite their corresponding surfaces in a symmetrical and regular manner, forming hard transparent crystals, resembling those of saline matters; which receive the name of *calcareous spars*. This is the last degree of attenuation to which chalk is liable, the state in which it differs most from its original character as part of an animal body, and bears the greatest resemblance to a real salt.

These transitions of cretaceous matters, through so many different states, the consideration of which opens to the naturalist such extensive views of the antiquity of this globe; the alterations which it has undergone, and the range of the animal kingdom, out of which so considerable a part of its surface and exterior strata is formed; these display to the eyes of the chemist nothing more than one matter, a neutral salt, formed by the combination of lime with the carbonic acid. We shall proceed to consider it under both these points of view.

§ 1. *Natural History of Calcareous Substances* *.

BEFORE entering into a particular detail of calcareous matters, it may be proper to take a general view of their disposition in the terrestrial globe. These substances are disposed in layers of a larger or a narrower extent, in an horizontal or an inclined direction, and impressed with the most unequivocal marks of their having been exposed to the action of a mass of water. These strata compose whole mountains and hills, &c. and form a considerable part of the crust or shell of our globe. They afford demonstration that our earth was once covered by the waters of the ocean, as they consist of the exuviae of its inhabitants. The waters filtrating through those calcareous masses, carry off part of their substance, and convey it deeper into subterraneous cavities, under the different forms which we are going to examine. The general characteristics which have been assigned them by naturalists, and which sufficiently distinguish them, are taken from two remarkable properties which they possess; they never scintillate with steel, and they effervesce with acids. As these calcareous matters appear under so many varieties of form, it becomes absolutely necessary to arrange them

* Although we have already, in the history of earths and stones, given methodical divisions of calcareous matters, which have been usually ranked by naturalists under that class of natural bodies; yet we think it proper to give here a new arrangement of them, founded on other considerations than those which have directed naturalists in their labours on this subject. A.

them under several genera. We admit six genera of calcareous matters *.

Genus I. *Earths and Stones, composed of Shells.*

THESE substances have been ranked among stones, as being apparently insipid and insoluble. But when analyzed, they are found to be actually saline, as well as all the following genera. They are known by their organic form; shells are often found in them unbroken: the stone is indeed nothing but an accumulation of those organized forms; and even the original colours of the shells sometimes appear in it. Sometimes too they are found to contain animals belonging to species which are no longer known to exist in the seas; such are several specimens of the *cornu-ammonis*, and all the *nautili*. Again, in Europe, and even in France, we find fossil shells belonging to species of animals which are not now known to exist any where but in America. Several naturalists have formed very extensive arrangements of fossil shells; but as they are the same with those of the living animals, we will treat of them elsewhere. There are likewise fossil remains of marine animal bodies, which cannot be referred to any known species of the present inhabitants of the ocean. Tho' we have no complete work on animal fossils, and this department of natural history have not yet been examined with so much care and accuracy as mineralogy;

* The reader may perhaps be surprised to meet with new generic divisions in the history of a species of salt: but these genera relate only to natural history, and are to be referred to the particular neutral salt which we are examining. A.

logy; yet we have descriptions of a great many of those bodies, which sufficiently prove that the seas have been once inhabited by species of animals which no longer exist.

When calcareous fossil bodies appear to have belonged to animals of a known species, they are then distinguished by a name referring to their origin, and usually compounded of the name of the class of the animals to which they belong, with the addition of a word or syllable denoting their state as stones; such as *madrepores*, &c. But it is to be observed that human bones, and the bones of quadrupeds, birds, and fishes, which have been buried under ground, though they be likewise known by the name of *fossils*, are not of a cretaceous nature; they retain their character of calcareous phosphate. And therefore *ornitholithes*, *ichthyolithes*, &c. are not to be ranked among cretaceous substances.

In describing organic substances, the origin of which is unknown, names have been assigned them, derived from their particular forms: of this kind are the *lapides judaici*, thought by some to be the speculæ of sea-hedge hogs; the *lapides numismales*, or *St Peter's pence*, resembling pieces of money, which appear to be small cornua Ammonis, arranged one over another: *fossil bezoar*, a kind of round mass or concretion in concentric layers; *ludus Helmontii*, the spaces of which appear to have been formed by the drying and shrinking of a soft earthy matter, and afterwards filled with calcareous earth; the *trochites*, *entrochi*, and *astroites*, which are produced from a zoophyte named *sea-palm*; and the *pisolites*, *oolites*, or *meconites*, which are thought to be petrified eggs of fishes or insects, but of which the true origin is unknown.

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To this genus of true calcareous stones, we likewise refer all petrified substances, to whatever animals they may have belonged; and natural history therefore enumerates here *gammarolites*, *cancrites*, *entomolites*, *amphibiolites*, *zoolites*, and *anthropolites*. But from the new discoveries concerning the nature of bones it appears, as we have already mentioned, that these matters are not to be considered as cretaceous. The same may be said of *glossopetra*, or petrified shark's teeth; ivory, or fossil unicorn, which is produced from elephants teeth; *turquoise*, or bones of green and blue colours; toad-stones, the grey or yellowish hollow stones; which, according to M. Jussieu, are the upper parts of the grinders of the Brazilian fish called *grondeur*; and *serpent's eyes*, which according to that naturalist belong to the incisive teeth of the same fish.

After this detail of particulars, we may venture to reduce this genus to two species, comprehending all its varieties.

Species.

1. Entire fossil shells.

These differ in colour, lustre, hardness, &c.

Under this species we include madrepores, and all calcareous habitations of polypi in the fossil state.

2. Falun, or cron.

Shells broken and reduced to earth. The soil of a part of Tourraine, and of several of the other provinces of France, is entirely of this nature. These earths are an excellent manure.

Genus

Genus II. *Calcareous Earths and Stones.*

THESE consist of the matters of the former genus, attenuated, dissolved, and afterwards deposited by water. They are found in banks or strata in the bowels of the earth. We follow M. Daubenton's division of the species of this genus.

Species.

1. Compact calcareous earth; chalk.

This substance varies in colour and fineness of grain; it is applied to a great many domestic uses.

2. Spongy calcareous earth; stone marrow.

3. Calcareous earth in powder; fossil meal.

4. Calcareous earth of the consistence of cream; lac lunæ.

5. Soft calcareous earth; tufa. This substance, as it dries, becomes hard and white.

6. Coarse-grained calcareous stone. Arcueil stone is a specimen of this. It is found to contain half-broken shells.

7. Fine grained calcareous stone. The thunder-stone is a variety of this species.

It would be improper to enter here into a minute detail of the varieties of these earths and stones: but it may be naturally imagined that there are a great many depending upon difference of colours and hardness, and the various purposes to which they are applied; and that those varieties are distinguished by different names. Almost all of them may be prepared as lime for the purposes of building, &c. &c.

Genus III. *Marble.*

MARBLES differ from calcareous stones properly so called, as being considerably harder. Like those, however, they do not scintillate with steel: they effervesce with acids, and their fracture is granulated; but their grain is much finer and closer; their colours are more brilliant, and they take a finer polish. All the world knows the application of marble, in sculpture, architecture, &c. It is used too in some countries for making lime.

Species.

1. *Lumachello.*

The Italians give this name to a species of marble formed by the agglutination of shells.

2. *Breccia.*

This is a species of marble consisting of small round masses, united by a cement of the same nature.

3. *Marble, properly so called.*

This substance exhibits neither the shells of lumachello nor the round masses of breccias; it is irregularly spotted, and sometimes round. M. Daubenton arranges marbles by the number and the combination of their colours, including under the same denomination both lumachellos and breccias.

1. Marble of six colours; specimen, white, grey, green, yellow, red, and black; Wittenberg marble.

2. Marble of two colours; specimen, white and grey; marble of Carana.

3. Marble

3. Marble of three colours ; specimen, grey, yellow, and black ; lumachello.

4. Marble of four colours ; specimen, white, grey, yellow, red ; brocatello of Spain.

5. Marble of five colours ; specimen, white, grey, yellow, red, black ; breccia of Old Castile.

4. Figured marble.

It represents ruins, as in Florence marble ; or herbs, as in Hessian marble.

It is to be observed, that the colours of marble depend almost always on the iron intermixed among its grains. This substance, though susceptible of a fine polish, is very porous ; every body knows that it is easily spotted : and this property renders it fit for receiving delineations of coloured flowers, and for being stained with many different colours.

Marble is often mixed with fragments of an hard stone, such as quartz and flint. The part which contains such fragments gives fire with steel. I have often observed this of several kinds of black marble.

Genus IV. *Concretions.*

CONCRETIONS are irregularly formed by the slower or quicker deposition of calcareous matter by water on the surface of some body. They are not disposed in extensive layers, but by fragments ; at first in insulated masses, which are at length united in one uniform crust.

Species.

1. Incrustations.

Waters impregnated with chalk deposite it on the surfaces of all bodies over which they flow: and incrustations may therefore be of all possible forms, corresponding to the forms of the bodies on which they are deposited. Such are those of the waters of Arcueil; such too is the Osteocolla, &c.

2. Stalactites.

These are gradually deposited by water in concentric layers, suspended from the arches of caverns, &c. They vary in size, transparency, or opacity, grain, colour, and form. They are generally hollow and pyramidal. *Flos ferri* is the purest of all substances of this kind. When they adhere to the sides of subterraneous cavities they receive the name of *congelations*; when deposited on the floor, they are called *stalagmites*.

3. Alabaſter.

Alabaſter ſeems to be formed of the pureſt ſtalactites, after they have been long buried under ground. It is ſofter than marble; and when poliſhed, its ſurface appears fat and oily. It evidently conſiſts of layers diſpoſed in various directions. It is always more or leſs transparent, which diſtinguiſhes it from marbles; but there are ſome ſpars which it never equals in transparency. Alabaſter poſſeſſes likewiſe all the characteriſtics of calcareous ſtones. It is cut into vaſes and ſtatues. There are many varieties of it.

Varie-

Varieties.

1. Oriental alabaster. This is the hardest and most transparent.
2. Occidental alabaster; not so fine and pure as the preceding.
3. Alabaster spotted with various colours.
4. Wavy alabaster. This is called *agate alabaster*.
5. Flowered alabaster; exhibiting specimens of herborization.

Genus V. *Calcareous Spar.*

CALCAREOUS spar differs from the four preceding genera in its form, which is generally more regular, and in its fracture. It is composed of laminæ arranged one above another, which are very discernible when it is broken. It crumbles down when struck with steel.

Species.

1. Opaque calcareous spar.
This is white or variously coloured; and usually appears in rhomboidal laminæ.
2. Rhomboidal transparent calcareous spar; Iceland crystal.
It represents objects double.
3. Calcareous spar in prisms without pyramids.

These are truncated hexahædral prisms, with faces either equal or unequal, and having sometimes their angles cut in such a manner as to make them twelve-sided prisms; which

Varieties.

circumstances give three varieties of this species.

4. Calcareous spar in prisms, terminating in two pyramids.

The varieties of this spar are pretty numerous. Some of them are hexahædral prisms, terminating in pyramids, which are also hexahædral, and either whole or truncated. Others display at the extremity of the hexahædral prisms, trihædral pyramids, either whole or truncated, or with dihædral summits. Lastly, There are some in quadrangular prisms, terminating in dihædral summits. All of these varieties exhibit sometimes one sometimes two pyramids, according to their disposition.

5. Pyramidal calcareous spar.

This is formed of one, or by the union of two pyramids, without any intervening prism. The hexahædral or triangular form of those pyramids, the inequality of their sides, and the frequent mutilation of their angles, distinguish them into a great many varieties *.

6. Calcareous spar in duodecagædral figures.

This spar, resembling a kind of granite or marcasite, appears to consist of two truncated pentagonal pyramids joined at their base.

7. Cal-

* The reader who wishes to be more particularly acquainted with the varieties of spars, may consult Dr Hill's work intitled, *The History of Fossils, containing the History of Metals and Gems, &c.* London 1748. Folio, with copperplates. M. Romé de Lille gives an extract from this work in the first edition of his *Crystallography*, page 131. *et seq.* p. 191, *et seq.* concerning calcareous spar and rock-crystals. He shows Dr Hill's method to be perplexed and defective, &c. A.

Varieties.

7. Calcareous spar in striæ.

This is a collection of long prisms, bundled up together in figures of no determinate regularity. The Swedish *lapis sicillus* belong to this species.

8. Lenticular calcareous spar.

This species consists of flat crystals, disposed obliquely, one beside another. M. Romé de Lille thinks it a variety of hexahædral prismatic spar, terminating in two obtuse, triangular pyramids, placed in opposite directions. *Cristallographie*, p. 123. *first edition*.

§ II. Chemical Properties of Calcareous Carbonate.

AS the chemical properties of bodies refer to their principles or combination, they should be distinguished by names expressive of their nature. The various calcareous matters which we have enumerated, are therefore to be confounded when we speak of them chemically under the general name of *Calcareous Carbonate*. Experiments for determining the properties of this earthy salt should be made either on the most transparent calcareous spar, or on pure white marble.

In order to analyze calcareous carbonate, we must first destroy its aggregation by reducing it to powder.

In this form it is white and opaque. It has no very sensible taste: but when kept for some time in the mouth, it contracts the fibres of the palate and the tongue.

When this earthy salt is exposed to the action of fire, it loses its acid and the water of its crystals. If suddenly exposed to a strong heat, it decrepitates and loses its transparency. By distilling it in a retort we obtain water and a considerable quantity of carbonic acid gas: but a strong heat is requisite to disengage the gas. After undergoing this operation, the calcareous matter is reduced to the state of quicklime: the salt may be formed again by combining the quicklime with the acid. Chalk, which differs from calcareous spar in no respect but in being less cohesive and opaque, has been distilled by M. Jacquin. The Duke de Rochefoucauld having repeated this experiment with much care, has observed that part of the aeriform carbonic acid escapes through the stone retorts used in distilling this substance. Dr Priestley has fully established this fact by a number of very accurate experiments. An iron retort, or the barrel of a gun, may be used on this occasion; but a little inflammable gas or hydrogen is always obtained at the same time, and is produced by the action of the water in the chalk on the iron.

When calcareous carbonate is exposed to a strong fire in clay crucibles, it melts into glass round the sides of the vessel. M. d'Arcet has melted pieces of several species into a spotted transparent glass. But as Macquer has observed that this earthy salt does not melt in the focus of M. de Trudain's lens, the fusion effected by M. d'Arcet was owing, doubtless, to the clay of the crucibles.

Calcareous carbonate suffers no alteration from pure air: but the rays of the sun acting upon it in a humid atmosphere, destroy its transparency and the cohesion of its laminæ. Its surface assumes the colours of the rainbow, becomes dark, and gradually deliquesces.

It does not appear to be soluble in water. Chalk, though not more soluble in this fluid than calcareous carbonate, is however maintained in solution by streams of water running over beds of cretaceous matter. In some instances water contains a considerable quantity of it. Of this kind are the waters of Arcueil near Paris; which contain so much chalk, that in a few months they deposit incrustations on bodies immersed in the canals through which they run. The bath waters of St Philip in Italy are so strongly impregnated with this substance, as to deposit layers of it half an inch thick in the space of a few days. Tablets and figures of this matter are obtained from these waters, by immersing into them hollow moulds, in which the cretaceous matter is accumulated.

Calcareous carbonate contributes to the vitrification of several earthy and stony substances: when mixed with siliceous earth in the proportion of two-thirds or three-fourths, it causes it to melt.

This salt, when mixed by nature with an argillaceous earth, composes a mixed earthy matter, to which naturalists and farmers give the name of *marl*. That substance of which there are very many varieties, differing from each other in colour, density, &c. melts, when exposed to a strong fire, into a greenish yellow glass. It is used with great success to soften and fertilize earths.

Barytes and magnesia have no action on calcareous

carbonate in the humid way: the carbonic acid has a stronger affinity with lime than with either of those two substances. But when calcareous carbonate is exposed to fire with these alkaline earths, it enters into a vitreous combination with them. M. Achard has made many experiments on all of those vitreous mixtures; of which a particular account is given in the *Journal de Physique*.

The fixed alkalis and ammoniac produce no alteration on calcareous carbonate, because the carbonic acid has a greater affinity with lime than with any of those salts.

The sulphuric, the nitric, the muriatic, and the fluoric acids decompose this salt by seizing its base and disengaging the carbonic acid. When the sulphuric acid is poured on calcareous carbonate, it excites ebullition, by disengaging the carbonic acid in a gaseous form. Naturalists have very happily assumed this property as a general characteristic of calcareous substances. With acids, an accurate analysis of calcareous carbonate may be effected. In order to this, let the salt be reduced to powder, and a quantity of sulphuric acid poured upon it. The violent effervescence which arises at the instant when the two substances are mixed, shows the carbonic acid to be then separated: and it may be obtained, and its quantity measured in a receiver, with the help of a syphon and bell-glasses filled with mercury. The effervescence is attended with cold, occasioned by the volatilization of the acid. When it ceases, if the new combination be examined, it is found to be calcareous sulphate, formed by the union of the sulphuric acid with the lime, which was the base of the former salt. Late experiments have shown,

shown, that several of these spars contain a little magnesia, and afford sulphate of magnesia, when dissolved by the vitriolic acid. The nitric acid commonly made use of by naturalists, in assaying calcareous stones, produces the same effervescence with calcareous carbonate as the sulphuric acid: it disengages the carbonic acid, and forms calcareous nitrate with its base.

The muriatic acid likewise separates the acid from calcareous carbonate with a violent effervescence, and produces muriate of lime by combining with its base.

The fluoric acid likewise decomposes this salt, forming calcareous fluuate with its base.

The boracic acid does not decompose calcareous carbonate cold; but causes it to effervesce when heated by being mixed with powdered chalk, and diluted with a sufficient quantity of water.

The carbonic acid renders carbonate of lime, or calcareous matters in general, soluble. We have already seen in the history of that acid, that it causes lime water to give a precipitate of chalk, but dissolves it again on the addition of more of the acid than what is necessary to effect the precipitation. Water impregnated with the carbonic acid, when left standing above a quantity of calcareous carbonate in powder, becomes at length impregnated with a certain quantity of this earthy neutral salt. Various waters acquire also chalk by means of the acid; but none of these solutions is lasting. When exposed to the air, they assume gradually a turbid appearance; and in proportion as the carbonic acid escapes, the chalk is precipitated. Heat causes this effect to take place much more rapidly. And for this reason, waters which are hard and crude by being
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impregnated with chalk, may be corrected by boiling.

As it is almost always owing to the carbonic acid that water maintains chalk in solution, we may naturally infer that this earthy salt must be precipitated when the acid evaporates. Such is the origin of the incrustations and accumulations of calcareous matter which are formed in fountains and on the sides of channels through which water of this character flows; as may be observed of the water of Arcueil and the bath-waters of St Philip in Italy. Before natural history was illustrated by chemistry, springs exhibiting such incrustations were called *petrifying fountains*, and superstition held them to be miraculous.

Calcareous carbonate does not act in any manner on neutral salts with a base of fixed alkali. It decomposes ammoniacal salts. By this decomposition we obtain on the one hand a calcareous salt, formed of the acid of the ammoniacal salt with lime; on the other, ammoniacal carbonate produced by the combination of the carbonic acid with ammoniac. This operation is performed by distilling in a stone retort a mixture of a pound of sal ammoniac with two pounds of chalk, or rather calcareous spar in powder. Both of these substances must be very dry. A long necked balloon must be fitted to the retort, or, what is still better, a stone or glass cucurbite. Fire is to be gradually applied till the bottom of the retort be made red-hot; and the receiver must be cooled with wet clothes, or with cold water kept running around it during the whole of the operation. White vapours arise, and are condensed on the sides of the receiver into very white pure crystals. These are ammoniacal carbonate. This is the process by which it is prepared in London, from which it was
for-

formerly retailed over all Europe under the name of *English sal volatile*. This salt is now prepared in other countries as well as in England. The residue after this operation is calcareous muriate with an excess of lime, generally in fusion if the fire has been strong towards the end of the operation.

Spar and calcareous matters in general are applied to many purposes, as we have already observed when treating of their natural history; but one of the most important is the preparation by which they are reduced to lime. The lime-burner decomposes calcareous matters, driving off their acid by the action of fire. Stones containing shells, marbles, and most calcareous spars, are the substances which afford the best lime: but the stone which is generally used for the purpose, more especially in the neighbourhood of Paris, is a kind of hard calcareous stone, known by the name of *lime-stone*. Those stones are built into a kind of oven or turret, forming an arch. A fire of wood is kindled under the arch, and kept up till a pure lively flame, without smoke, arise about ten feet above the oven, and the stones become very white. They are now beginning to use mineral coals and peats in the neighbourhood for burning lime.

Good lime is hard and sonorous, and becomes very hot on being brought into contact with water, and when flaked exhales a thick smoke. When not sufficiently calcined, it is not so sonorous, nor does it become so soon hot with water, or to so high a degree. If too much burnt, it is half vitrified; it then yields, when struck, too clear a sound, and does not unite readily with water. The lime-burners then call it *burnt lime*. We need not here speak of the purposes to which
lime

lime is applied, as we have taken notice of them in treating of the pure substance.

We may here add, that the calcareous carbonate, which is found mixed in very small fragments with calcareous sulphate, and exists in mountains, in extensive strata, most commonly regular, and separated by clay and marl, as in the vicinity of Paris, is the best plaster stone for building. Though we have already adverted to this in the article of calcareous sulphate, it may be not improper to return to it in this place, and to enter into such a detail of particulars as may supply what is wanting on this head in all works on natural history and chemistry.

We must first recollect that pure calcareous sulphate gives only fine plaster by calcination; which makes but an incoherent paste with water, and is cast into statues. It is universally known, that this paste when dry is not tenacious, and is so brittle that the smallest degree of resisting force is sufficient to break it. The reason is, that when this saline matter regains the water which is lost by calcination, it forms an equal homogeneous mass. This is by no means the case with plaster fit for the purposes of building. The stone which affords it at Montmartre and other places, is a kind of breccia, consisting of very small granulated crystals of sulphate of lime, with very thin plates of calcareous carbonate. The presence of the latter substance may be determined by dropping a little of the nitric acid on the stone: it produces a lively effervescence by disengaging the carbonic acid. If a given weight of Montmartre plaster stone be dissolved in a sufficient quantity of aquafortis, the calcareous carbonate is entirely decomposed, when the
lime

lime unites with the nitric acid, and what remains is calcareous sulphate, a substance insoluble in that acid. This experiment shows, that the proportion of calcareous carbonate varies in different plaster stones; and that in the best it constitutes rather more than a third part.

This fact concerning the mixed nature of plaster stones being fully established, it is easy to comprehend the nature of the phænomena which building plaster exhibits when burnt, flaked, and hardening. When this earthy salt is burnt, the calcareous sulphate which it contains loses the water of its crystals, and becomes friable; while the calcareous carbonate, at the same time losing its acid, becomes a calx. On this account, plaster which has been properly burnt is acrid and alkaline, communicates a green colour to syrup of violets, acquires heat when brought into contact with the acids, without effervescing, and gradually loses its strength when exposed to the air, in proportion as the quicklime which it contains is flaked, by attracting water and carbonic acid from the atmosphere. When wrought into mortar, it gives out heat, in proportion as it absorbs water. As to its solidity (which it is well known to assume very readily), a characteristic property in which it is directly opposite to pure lime, the quicklime contained in the mass soon absorbs as much water as is requisite to flake it, and the calcareous sulphate intermixed among its particles, likewise attracting a certain portion, is suddenly crystallized, and acts the part of sand or cement, by uniting and consolidating the lime.

/ Lastly, This theory explains why plaster retains its cha-

characteristic properties, when kept dry, and exposed to heat; but when exposed to moisture, gradually loses them and wastes away. These phenomena are owing to its being composed of two saline principles, both soluble in water.



END OF VOLUME FIRST.

